FINAL REPORT ON DEVELOPMENT

of

EQUIPMENT FOR THE TRANSITION/TERMINAL AREA SUBSYSTEM

of

THE AIR TRAFFIC CONTROL DATA PROCESSING CENTRAL

PREPARED FOR

FEDERAL AVIATION AGENCY,
AVIATION RESEARCH & DEVELOPMENT SERVICE

CONTRACT NO. FAA/BRD 318

BY

TASKER INSTRUMENTS CORPORATION

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FINAL REPORT ON DEVELOPMENT OF EQUIPMENT FOR TRANSITION/TERMINAL AREA SUB-SYSTEM OF THE AIR TRAFFIC CONTROL DATA PROCESSING CENTRAL

Contract: FAA/BRD-318

Prepared for:

Federal Aviation Agency
Aviation Research & Development Service
Washington 25, D. C.

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This report has been prepared by Tasker Instruments Corporation for the Aviation Research and Development Service (formerly Bureau of Research and Development). Federal Aviation Agency, under Contract No. FAA/BRD-318.

ABSTRACT

Tasker Instruments Corporation (TIC), as a member of a team with General Precision Laboratories (GPL), Link, Librascope, etc., submitted proposals (to GPL who submitted a master proposal to the Government) for the Transition/Terminal Area portion of the Airways Modernization Board's (AMB) proposed National Air Traffic Control System. Upon consummation of the contract with the team and upon the assignment of GPL as the Prime Contractor, the other team members were issued subcontracts by GPL for each member's portion of the work as proposed.

The prime contract with GPL was numbered AMB-9 until the Federal Aviation Agency (FAA) replaced the AMB, after which the prime contract number was changed to FAA/BRD-9. The TIC subcontract with GPL was numbered GPL P.O. G-24470-6. This subcontract was in effect until shipment of all equipments, after which the FAA assumed the cognizance for contract completion and changed the contract number to FAA/BRD-318. This final report has been prepared using the FAA/BRD-318 contract number.

The TIC subcontract covered the design and the development and manufacture of many of the equipments of the Transition/Terminal Area portion of the FAA's Data Processing Central system. GPL functioned as the prime contractor, issuing and changing specifications and coordinating the effort. The GPL governing technical specification to TIC was GPL No. 10000-523 plus the change orders. This specification contained a general approach to the problem. The original concept governing the configuration of the equipment to be delivered dictated the use of off-the-shelf components that would result in an evaluation model. After evaluation by the customer, a prototype model was to have been fabricated making full use of the evaluation data. However, during the course of development, it became evident that off-the-shelf components were not suitable for use in the system design which had evolved at this point. Therefore, the equipment finally delivered approaches the configuration representative of prototype equipment.

This final report has been prepared on the basis of a minimum cost type report for use of engineering-level personnel, to cover the design, manufacture and test of equipments under the TIC subcontract.

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INTRODUCTION

PURPOSE

This Final Report reviews the design, fabrication and testing of equipments manufactured by Tasker Instruments Corporation for the Federal Aviation Agency, Bureau of Research & Development, Washington 25, D. C., under Contract FAA/BRD-318, for use in the Transition/Terminal Area Portion of the Air Traffic Control Data Processing Central.

SCOPE

The equipment consists of the following units:

TABLE 1. EQUIPMENT SUPPLIED

Qty.	Part No.	Unit	Function
1	3580	Video Track Programmer (VTP)	Program and control
1	3579	Conditioner-Generator Unit - Type I	Contain common equipment
1	3597	Conditioner-Generator Unit - Type II	Contain common equipment
2	4951	Character Generator (2 chássis)	Position characters on PPDD
2	4952	Video Conditioner	
	3069	Precision Sweep Generator (2 ea.)	Generate resolved radar or beacon sweeps
	3090	Waiting Point Generator	Generate Tracker x, y, and z waiting point voltages
	3108	Synchronizer	Buffer positioning and control voltages
	3164	Video Processor	Standardize radar and beacon video

TABLE 1. EQUIPMENT SUPPLIED (continued)

Qty.	Part No.	Unit	Function
1	3409	TCP Lamp Driver	Control Tracker Control Panel indications
1	4674	Digital to Analog Converter	Convert digital data into x, y, and z analog voltages
1	5780	Approach Display Processor Assy. (2 chassis)	Control Approach Display Assemblies
3	3562	Video Tracker Unit	House Video Trackers
25	3186	Video Trackers	Track approaching aircraft
6	3796-1, -2	Tracker Control Group	
	3691-1, -2	Tracker Control Panel (3 of each type)	Select Trackers, video, etc.
	3685	Slew Control Unit	Slew Trackers
	3688	Tracker Control Auxiliary	Process control signals and status signals
1	5711	PAR Console	Monitor aircraft on final approach
1	4759	Approach Display (PAR)	Display aircraft identities and time to fly
1	4579	Approach Display (Local)	Display aircraft identities and time to fly

The initial issue of GPL Specification 10000-523 specified an Analog Computer and two models of the Video Track Programmer, Type I and Type II. The Video Track Programmer Type II was intended to operate in a system which contains the

TIC designed Analog Computer and the Video Track Programmer Type I was intended for a system which did not contain the Analog Computer. Subsequently, the specification was revised and requirements for the VTP Type II and Analog Computer were deleted.

However, considerable design work had been accomplished on these two items prior to their deletion. The design of the Analog Computer is therefore covered in detail in the body of the report. This information should be valuable in helping to avoid repetition of design effort should a similar analog computer be incorporated as a modification of the present terminal area configuration. Information regarding the Video Track Programmer Type II is given in the discussion of the Video Track Programmer Type I.

ORGANIZATION

The report is divided into three sections: Section I - Equipment Design, Section II - Tests and Test Results, and Section III - Conclusions and Recommendations.

In Section I, each major unit is discussed in detail on the sub-unit or chassis-group level. The discussion for each major unit is divided into four parts as follows:

a. Design Objectives - This part of the discussion sets forth the functional requirements of the unit (or sub-unit) and the relationships between the unit and other portions of the system.

b. Design Alternatives - The design approach is explained by listing each alternative method for implementing the function and explaining the advantages and disadvantages of each alternative.

c. Final Design - The reasons are given for selecting the final design in preference to other alternatives. The final design is also described in detail with explanations of major design problems and significant engineering changes which were incorporated after the equipment had been built.

d. Recommendations - Modifications for improvement of the present design are recommended. Some of the recommended modifications were considered desirable while the equipment was still in the stages of design and fabrication but were not incorporated because of cost, schedule, or state of the art at that time. The particular reasons for not implementing the modifications are also given.

In the case of the Conditioner-Generator Unit and its contents, design objectives, design alternative, final design and recommendations are discussed for each sub-unit or chassis-group. This is done because the Conditioner-Generator Unit contains several non-related functional entities.

Section II, Tests and Test Results, contains a review of the acceptance testing program. The complete test program for the Tasker designed equipments included bench tests, box tests, and unit tests (tests of equipments in groups). Section II is devoted to unit testing as all previous tests were intermediate steps toward the systems type unit tests.

Section III, Conclusions and Recommendations, contains a review of the acceptance test results as outlined in the histories of the unit tests (Section II). In particular, those areas where tests were partially passed are explained. The corrections are outlined and the dispositions of the tests are given. Where test data was obtained from NAFEC between January 16 and July 6, 1961 and the data was used to indicate that certain test sections were passed, the corresponding test paragraphs are indicated. Section III also contains recommendations for equipment modifications and recommendations for changes to product specifications and test specifications. These changes are recommended to make the equipment meet the DPC system requirements more adequately.

SYSTEM DESCRIPTION

The Video Tracking System receives primary radar and beacon data, data inputs from the Transition Data Processing Group (TDPG), and command inputs from the controller. Radar and beacon data are processed by the Video Conditioner. Data inputs are stored by the Video Track Programmer and command inputs are stored either by the Video Track Programmer or in associated circuitry. These types of data, along with information which is internally generated by the Video Tracking System (Video Trackers) are used to track aircraft automatically and provide surveillance and control information for the control of air traffic within the Transition Terminal Area. The Trackers receive standardized video which is of constant amplitude and duration and, if the video input to the Video Tracking System is not standardized, the Video Conditioner performs this function. Raw radar and beacon signals, however, are sent from the Video Conditioner to the PPD Displays for display on the direct-view storage tube. Character select and positioning information is also forwarded (via Character Generator) to the direct-view storage tube to produce the desired bright-tube display consisting of combined radar and beacon pictorial and alpha-numeric presentations.

Inputs from the Transition Data Processing Group are also utilized in presenting a tabular display of the identity and time to fly of the next five aircraft to land, by means of electromechanical alpha-numeric indicators which are mounted at the Local Controller's console and at the Precision Approach Radar (PAR) console. In addition to the above Video Tracking System, the TIC subsystem includes the PAR Console, which has been designed as the GCA controller's console for use with either the PAR-1 or the FPN-16 precision approach radar.

In order to aid the controller in his nearly continuous monitoring of aircraft within the Transition Terminal Area, a pool of Video Trackers (up to 50 Trackers) utilizes

TIC designed Analog Computer and the Video Track Programmer Type I was intended for a system which did not contain the Analog Computer. Subsequently, the specification was revised and requirements for the VTP Type II and Analog Computer were deleted.

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video from radar and beacon sources to display the position of up to 50 aircraft on the PPDD's. Rectangular tracking gate outlines are presented which outline the target, when an aircraft is being tracked. Identity and control information is presented adjacent to each tracking gate on the display tube in the form of an ID leader (identification or association between gate and characters), a Bar (tracking status) and a 19-character alpha-numeric display (aircraft identification, local track number, height, destination, landing sequence number, control instructions).

Additional primary functions of the tracking system are:

a. To transmit tracker status information to the T/T Computer.

b. Make available Tracker coordinate positions (x, y, z) for the T/T Computer analyses in providing landing sequence control instructions.

c. Make specified information available for the controller's visual use on the PPDD relating to missed approach and landing sequence.

d. Beacon codes assigned to each specified aircraft are used for positive tracking and identification.

The tracking system may operate in an automatic or coast mode after the controller manually acquires the targets.

The VTP, Trackers and Tracker Control Panel (TCP) may be used in either a one-pool or a two-pool system configuration as follows:

a. One-Pool -- In the one-pool system configuration, the system utilizes target information from only one radar and one beacon in order to track aircraft. A memory drum in the VTP stores information concerning the status of the ten TCP's and the 50 Trackers (in groups of 25). Any available tracker of the 50-Tracker pool may be assigned by the VTP to any one of 10 TCP's. The Trackers operate with standardized target video and sweep trigger pulses from Radar No. 1 and Beacon No. 1.

b. Two-Pool -- In the two-pool system configuration, the system utilizes two radars and two beacons to track aircraft. The VTP memory drum stores information concerning the status of two groups of five TCP's and 25 Trackers. In either pool, any one of the 25 Trackers may be assigned by the VTP to any one of the 5 TCP's. The 25 Trackers of Pool No. 1 operate with target video and sweep triggers from Radar No. 1 and Beacon No. 1. The 25 Trackers of Pool No. 2 operate with Radar No. 2 and Beacon No. 2.

For the purpose of further discussion, the Video Tracking System may be considered to have two primary functions; the video tracking function and the display function. The video tracking function is accomplished by the 3-D Video Trackers, the Video Conditioner Group, the Tracker Control Groups (as many as 10) and the

TCP Lamp Driver (refer to Table 1). The Video Track Programmer (VTP) is also utilized in performing the tracking function. It assigns Trackers to targets and to Tracker Control Panels and controls the time sharing of Tracker displays on the PPDD. The display function is accomplished by the Character Generator, Digital to Analog Converter, portions of the Video Conditioner Group and a group which consists of the two electromechanical Approach Display assemblies (Local and PAR). The Video Track Programmer is also utilized in performing the display function. It controls the timing and positioning of the alpha-numeric display and other display symbols on the PPDD and also controls the alpha-numeric Approach Displays. The PAR Console, which is not functionally related to the above equipments, will be described separately.

Status information which is stored by the VTP for the video tracking function and the display function is as follows:

a. Direction (off-set) of the 19-character format location on the PPDD storage tube with relation to the corresponding tracking gate outline (any of eight directions may be selected at the TCP for each Tracker).

b. The location of waiting points. A waiting point is an aircraft point of entry into the terminal area. When the VTP assigns a Tracker to an approaching aircraft, the tracker automatically slews to a waiting point. This is done to facilitate acquisition of the new target by the controller. Four of sixteen waiting points are pool locations for substitute Trackers.

c. Data for the alpha-numeric character displays on the PPDD, such as aircraft identity, altitude, position in the landing sequence, status of the aircraft (early or late) local track number, destination, and computer readout characters.

d. Special display information which may have been requested by the operator, such as, Missed Approach, Scramble Corridor, Return to Base, and Landing Sequence.

e. Identity and time to fly of the next five aircraft to touch down, for use by the electromechanical Approach Displays.

Operator procedures for calling up a Tracker, slewing the Tracker during target acquisition or rate-aided tracking, dumping a Tracker, etc., are explained in the respective equipment instruction books. Therefore, only the sequence of signals and integration of elements of the system will be discussed in this report.

The Tracker Control Group consists of a Tracker Control Panel, Slew Control Unit, and Tracker Control Auxiliary. The Tracker Control Panel and Slew Control Units are operator controls, while the Tracker Control auxiliary contains only circuitry for processing signals. Also as shown in the diagrams (figures A thru C), the Video Conditioner Group (located in the Conditioner-Generator Unit) contains two Precision Sweep Generators, a Video Processor, a Waiting Point Generator,

and a Synchronizer. These units are either used by all Trackers (common output) or are time shared between the Trackers. The TCP Lamp Driver is physically located in the Conditioner-Generator Unit but is functionally a part of the Video Track Programmer. The 50 Video Trackers are assembled into cabinets containing 25 Trackers per cabinet.

The Tracker request message is received from the TDPG Computer by the VTP in the form of a serial message which contains Tracker Control Panel number, file number of aircraft identification, offset indicator, leader control, waiting point, and 19-character format information. The VTP stores this data in accordance with the correct Tracker Control Panel and assigns a Tracker. The VTP causes the TCP Lamp Driver to make the next unused Tracker Selector button glow dimly on the Tracker Control Panel and causes the Waiting Point Generator and D/A Converter to supply the desired Tracker Waiting Point position voltages to the coordinate inputs of the position storage amplifiers of the selected Tracker. The operator then pushes the dimly glowing Tracker Selector Button, selects the type of video and ID leader desired, places the Tracker in the slow or fast slew mode via the Tracker Control Panel pushbuttons, and slews the Tracker until the slew dot is directly over the target. He then pushes the video selector button and the tracking gate appears with the Tracker in the auto-track mode.

The VTP controls as many as ten Tracker Control Panels, devoting a period of 1.6 milliseconds to each panel (one-tenth revolution of the memory drum). During the 1.6-millisecond period, a TCP select gate is generated by the VTP, enabling all pushbuttons on the panel. At this time, ID offset direction data can be entered on the drum. The VTP also sends control signals to the assigned Tracker to enable its logic inputs. Thus the video select data from the TCP is entered into the Synchronizer, which in turn sets the affected control flip-flop circuits in the Tracker to cause 1) the Tracker inputs to be connected via relays and diode switches to the selected radar or beacon sweeps and 1 of 6 types of radar video or beacon video, and 2) the Tracker outputs to the slew (time shared) position lines.

When in the slew condition, the Synchronizer generates slew enable gates at a 60-cps rate which connect the Tracker outputs to the slew (time shared) position lines. Also, the Synchronizer is instructed to set the affected control flip-flop circuits in the Tracker to cause the slew-stick generated signals to be entered into the x and y storage amplifiers via the correction relay circuits in the storage amplifiers. The slew-stick generated signals are actually x and y slew correction voltages obtained from the slew stick x and y tachometers. (By closing the switch on the Slew Control Unit joystick, the operator energizes the x and y tachometers. Then by moving the joystick in the direction he desires, causing the tracking gate outline and/or slew dot to move, he generates both x and y voltages. The operator then releases the handle switch before returning the slew stick handle to the neutral position.) The x and y tachometer voltages (ac) are amplified, phase detected to obtain peak voltages, and stored in the Tracker Control Auxiliary. These stored voltages are sampled at a 60-cps rate by the Synchronizer generated slew enable

gates to form the slew correction voltage inputs to the Tracker x and y storage amplifiers (1.6-millisecond amplitude-modulated pulses).

When a Tracker loses a target, the gate size automatically increases in an attempt to reacquire the target, and the Tracker selector pushbutton blinks. At the same time a signal is sent to the Synchronizer which enables a blink signal generator. Thus, the status light on the Tracker Control Panel will fluctuate in brightness. The operator may now push the tracker selector button and POS (position) and SLEW buttons for this off-target Tracker, and reposition the tracking gates onto the target using the slew stick which involves circuits previously discussed.

The other units involved in the tracking operation are the Precision Sweep Generators and Video Processor. The Precision Sweep Generators receive the synchro (angle) data direct from the radar or beacon source along with the system trigger, and convert this data to precision Cartesian coordinate sweep voltages. The Video Processor unit receives the various radar videos and the basic beacon and z beacon video from the radar or beacon source to standardize and range mix radar videos. The outputs of these units are used by all Trackers in parallel.

The display function elements have been previously described and only their use will be further elaborated upon. The VTP receives from the TDPG all alpha-numeric data to be displayed by the PPDD system and the Approach Displays. The tracking system provides the remaining input signals required.

The alpha-numeric data to be displayed in the 19-character ID format is stored in the VTP along with other Tracker data according to Tracker number. Also stored in the VTP, according to Tracker Control Panel number, are the special display data. Thus, once each 3 seconds, during display printout, the data concerning each Tracker and its TCP number is sent to the Character Generator. The Character Generator processes and converts this data into ID leader sweep voltages, bar status voltages, character selection voltages, character position voltages and their corresponding intensity pulses. The ID leader, bar and character position voltages are summed at the offset and incremental deflection lines. The character selection voltages are buffered at the character select and compensation lines. These signals, along with correct (1 of 10) TCP display gate, are sent to the PPDD system for print out of the Tracker identity and control information. Because the TCP Display gate enables only the PPD Display from which the Tracker is being controlled, though all PPD Displays will show all tracking gate outlines, only the Trackers (gate outlines) under control from that particular console will contain ID leaders and ID tags. The special display print-out data is also associated with the TCP gate of the console which requested the special data. Thus, for example, five special displays may be presented at the same time, one on each console. The sequence for print-out special displays is slightly different between the first printout and subsequent printouts. During the first print cycle after the operator requested a special display, an override call-up gate is generated, which causes the display to be printed immediately. Subsequent character format displays are

printed according to the countdown selected in the PPDD system. Also during special display, the Character Generator adds to the offset and incremental deflection lines the console controlled special display call-up position voltages for correct gross positioning of the data in the video blanked area of the PPD Display.

The printup of Mode B circles (which denote the scheduled position of the aircraft) and their associated leaders requires not only the Tracker position voltages, as in ID leader and ID tag print, but also the difference voltage between the actual Tracker position and the computed ideal position of the aircraft. The actual Tracker position voltage is time shared on the print coordinate lines to the PPDD system without additional signals from the Character Generator during ID tag print. During Mode B circle print, the computed correct coordinates of the aircraft are subtracted from the Tracker actual coordinate voltages in the Digital to Analog Converter. This difference voltage is routed to the Character Generator where it is used to determine the resultant Mode B circle leader direction and length. These sweep voltages are then routed to the Synchronizer where they are summed with the Tracker actual position voltages, the Mode B circle sine-wave voltages and the Print Coordinate (x and y) lines. The resultant display is a leader starting from the Tracker actual position and extending to the computed correct position of the aircraft which is represented by the circle.

The Approach Display Processor and Approach Display (Local and PAR) Units operate entirely from data received and stored in the VTP, which data is received from the TDPG. The Local and PAR Displays are almost identical in their circuit configuration and mechanical appearance, and operate in parallel from the Approach Display Processor signal lines. Both the Local and PAR Displays contain five rows of ten indicators. The Local Display contains a 6th row of alphanumeric indicators which display the identity of the last aircraft to reach touchdown and three control buttons: Start, Missed Approach and Touchdown. The first seven indicators (left to right) of each row are used to display the aircraft identity, and the last three indicators are used to display the time to fly of those aircraft, if any, within 9 minutes and 55 seconds of reaching touchdown, and which occupy the corresponding five landing sequence time slots. If a landing sequence time slot is not occupied, then the seven identity indicators will display blank symbols and the time to reach touchdown indicators will display zeros. The Approach Display Processor receives new data from the VTP at approximately three-second intervals. This data is for either a seven-character identity update (row update) or a time to touchdown (15 indicator) update. During start up, the Processor enters first the bottom row of identity data and then a time update. Next row up then receives the identity and update etc., until the top row has been entered. Thus, the time to touchdown is always current for all identities displayed. During subsequent laddering down of identity data from the top row to each row below (as the landing sequence time slot approaches touchdown) a time update is performed after each row downshift in such a manner that the row of data just laddered down will have its correct time displayed, and all time displays thus still correlate with their respective identities.

The operation of the Processor and Approach Displays is only slightly different for missed approach and touchdown. During touchdown sequence, all rows ladder to the row below starting with the next to bottom row. Then after the top row has laddered to the next-to-the-top-row, and a time update is completed, the new aircraft identity data is entered into the top line. For a missed-approach sequence, the bottom line (touchdown) is not changed, and the laddering down process eliminates the aircraft and its time-to-fly data which appeared in the next to bottom line. Thus a missed-approach or a touchdown procedure must not be started until the affected aircraft is in the fifth row.

The PAR Console is a remote display indicator for use with either the PAR-1 or AN/FPN-16 radar systems. The console utilizes a 21-inch direct view storage tube as the display indicator and may be operated under normal ambient light conditions. The unit was designed for one-or two-man operation, and contains electronic control and presentation of video mapping and data presentation which includes range marks, antenna position servo data, upper and lower ILS limit lines, and glide slope and course center line cursors. This console receives system triggers and antenna angle data from either the PAR-1 or AN/FPN-16 radar set and converts this data into plan and elevation position indication display. Elevation angle versus radar range is displayed in the upper portion of the cathode ray tube while azimuth angle versus radar range is displayed in the lower section.

The integration of the PAR Console into the DPC System is as follows. When an aircraft has entered the final leg and is approaching touchdown (at a distance of approximately ten miles) the control of the aircraft is transferred from the approach controller to the local controller. During the remainder of the aircraft letdown the PAR Console is utilized as either an ILS monitor or as a GCA direct view aid.

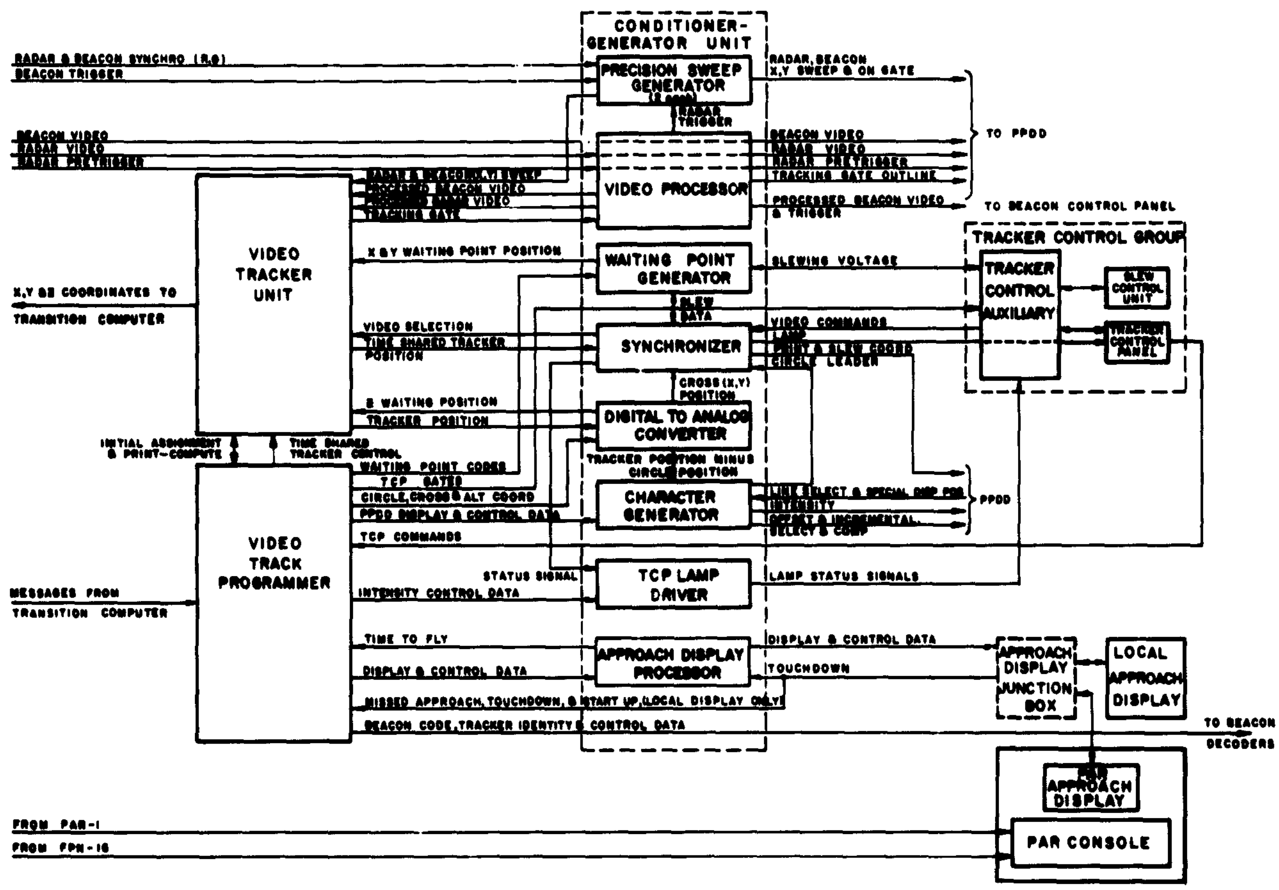

Figure A. Video Tracking System, Simplified Flow Diagram

VIDEO TRACKING SYSTEM

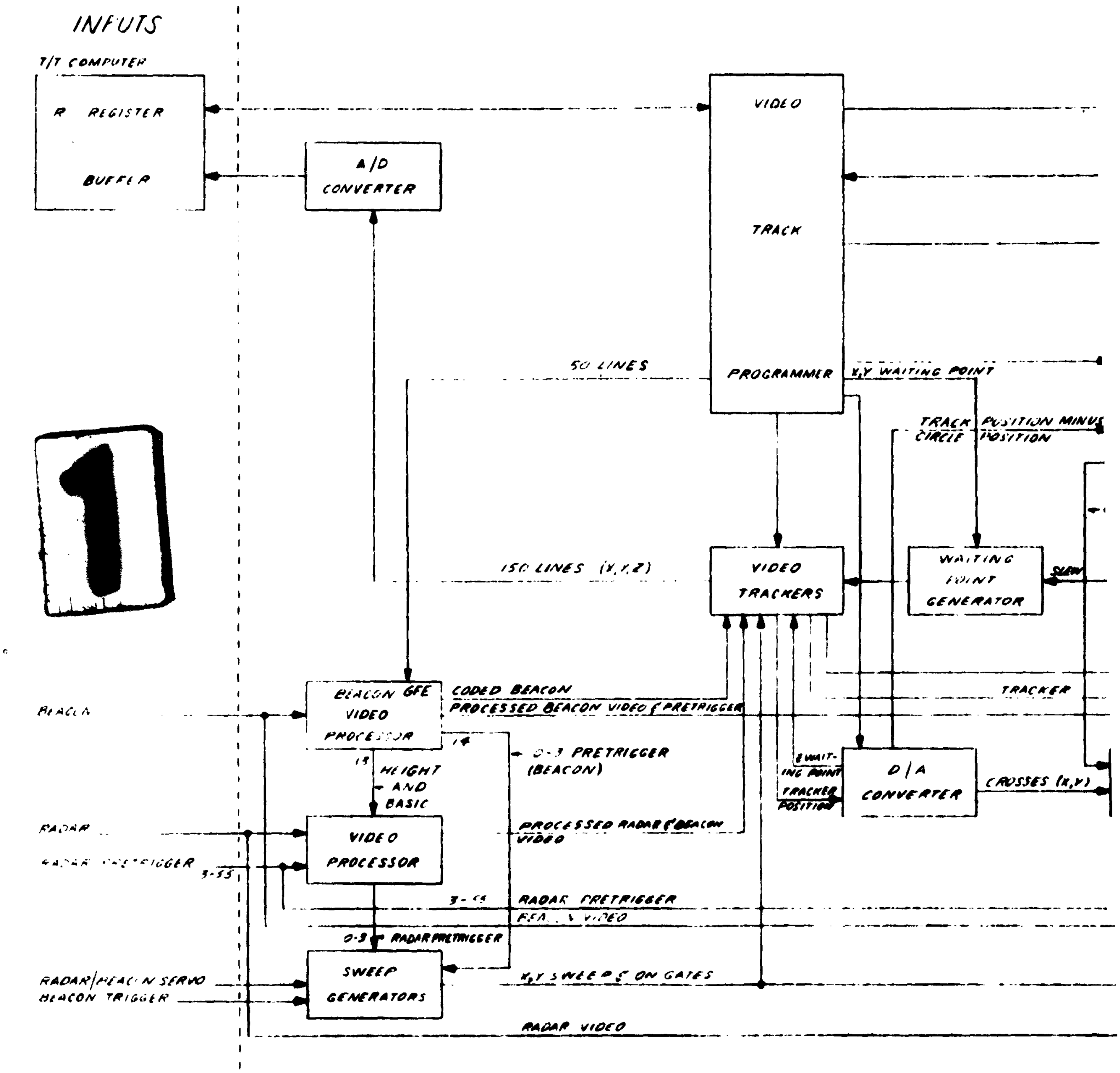

Figure E

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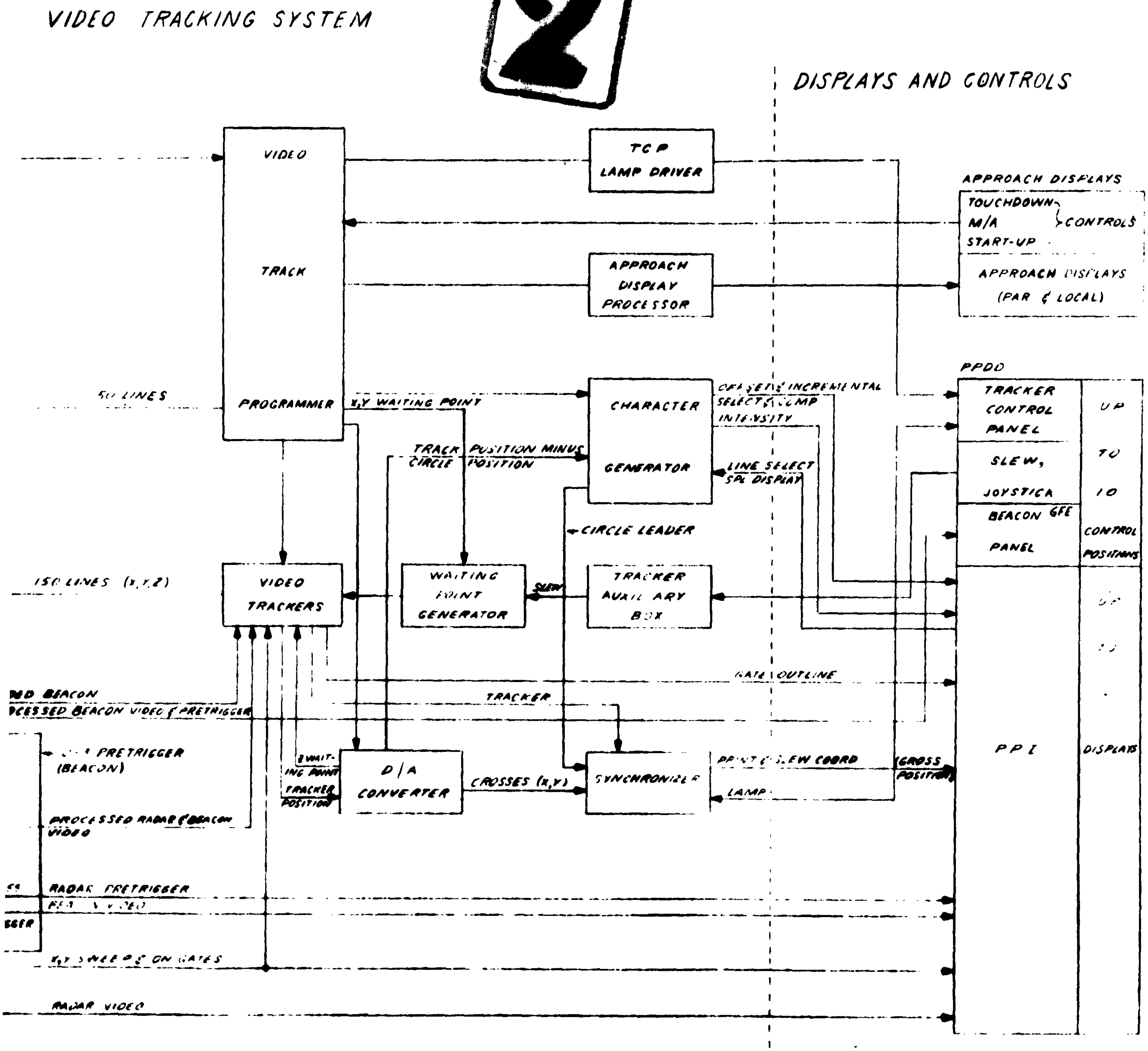
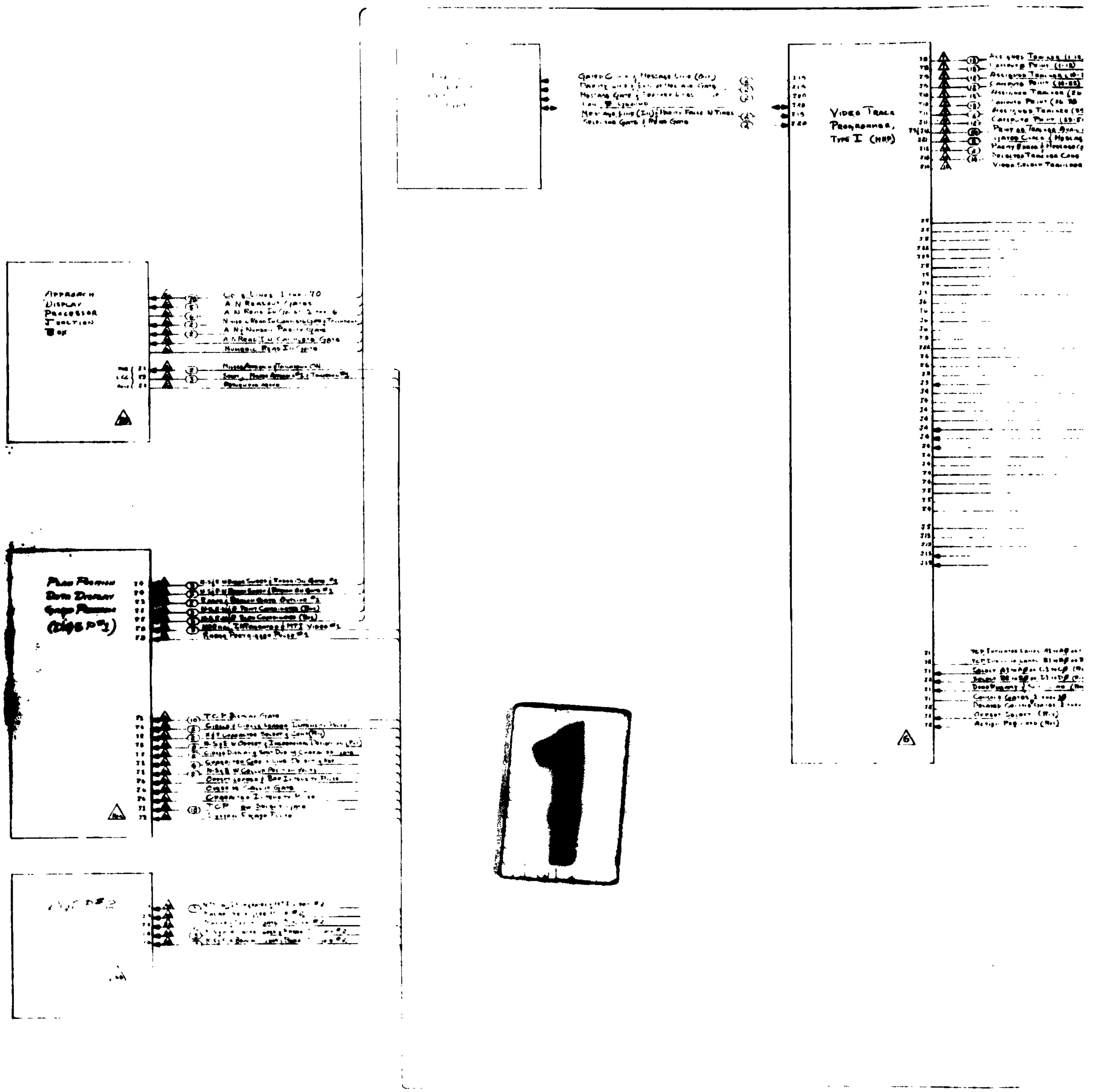


Figure B. Video Tracking System, Simplified Block Diagram


Approach Display Processor Function Box
Video Track Programmer, Type I (NHP)
1

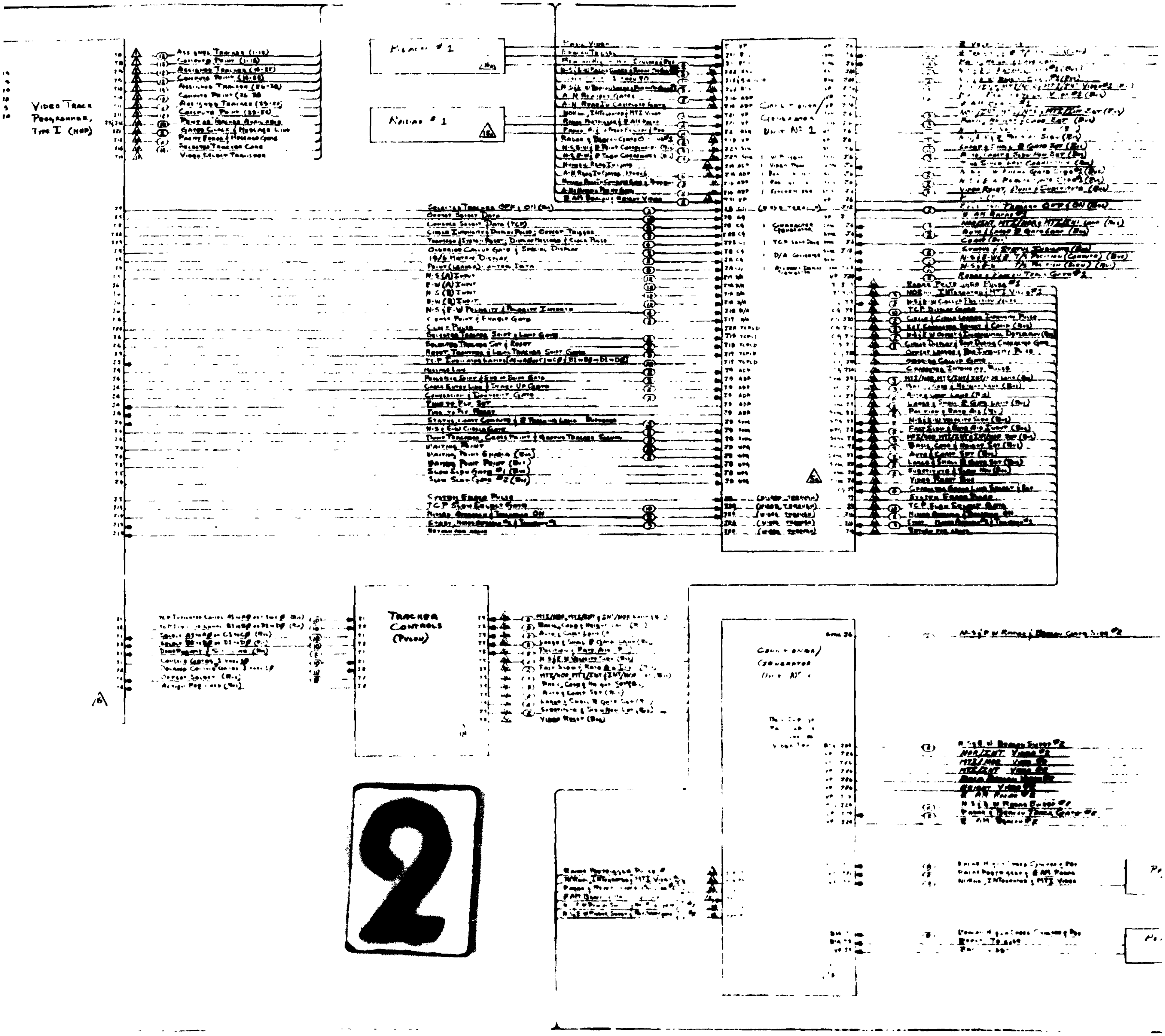
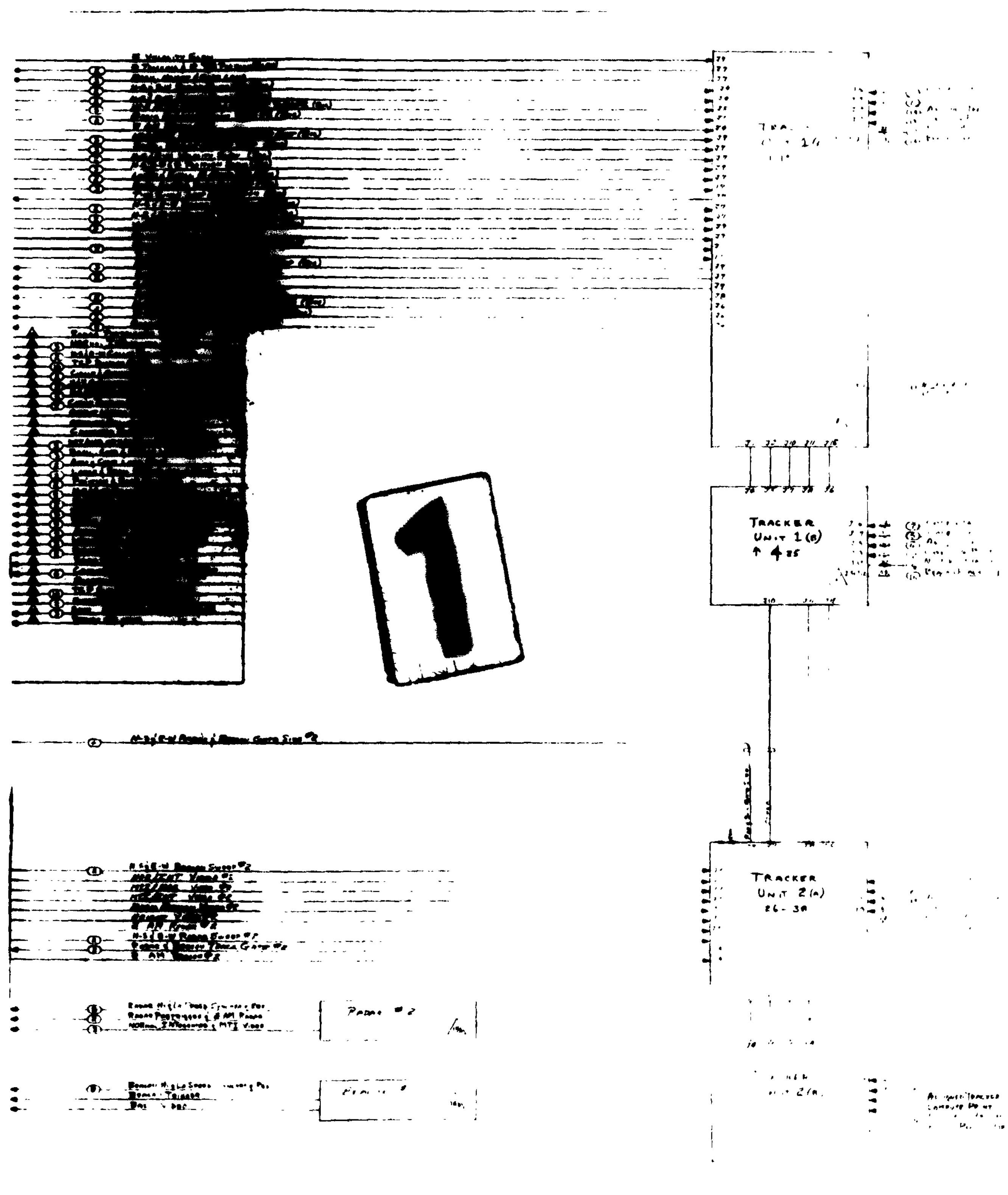


Figure C. Signal Flow Diagram For Two-Pool Tracking System



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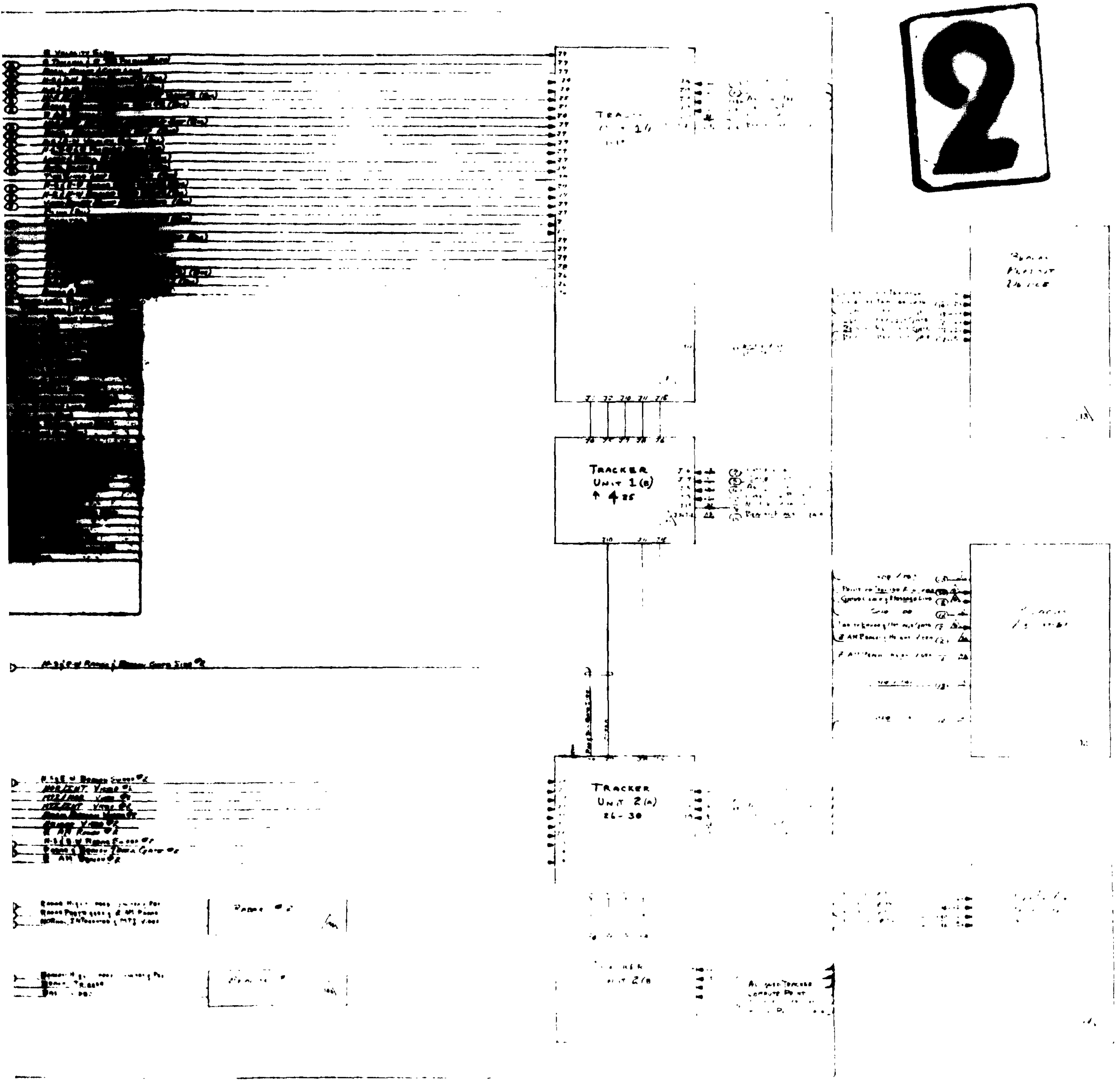

Figure C. Signal Flow Diagram For Two-Pool Tracking System

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SECTION I

EQUIPMENT DESIGN

1.1 CONDITIONER-GENERATOR UNIT - The Conditioner-Generator contains the following sub-units and chassis groups as shown in Figure 1.

1. Video Conditioner
   a. Precision Sweep Generator (2 each, radar and beacon)
   b. Waiting Point Generator
   c. Synchronizer
   d. Video Processor
2. Character Generator
3. TCP Lamp Driver
4. Digital to Analog Converter
5. Approach Display Processor
   a. Conversion Display Processor
   b. Control Display Processor
6. Power Supplies

1.1.1 VIDEO CONDITIONER

1.1.1.1 PRECISION SWEEP GENERATOR

1.1.1.1.1 DESIGN OBJECTIVES

The purpose of the Precision Sweep Generator (figure 1) is to convert radar or beacon data from the R, θ coordinate system of the radar or beacon into x-y coordinate information. This is accomplished by generating x and y sweep voltages as a function of R, θ inputs, using a fixed sweep into a servo-driven precision resolver. These inputs, x and y, are clamped and buffered. The outputs of the Precision Sweep Generator are used by the Video Trackers and the PPD Displays.

1.1.1.1.1.2 TRIGGERING - The input trigger from the radar or beacon is variable from a prf of 100 to 2000 pps or 50 to 500 pps respectively. The pulse height is variable from 5 to 50 volts when terminated by 75 ohms. The pulse width is variable from 0.3 microsecond to 3.0 microseconds (radar) or 0.3 to 1.5 microseconds (beacon). The rise time is between 0.05 and 0.5 microsecond (radar) or .02 microsecond or less (beacon). It may be a zero-range trigger or a pretrigger as much as 55 microseconds prior to zero-range time (radar) or

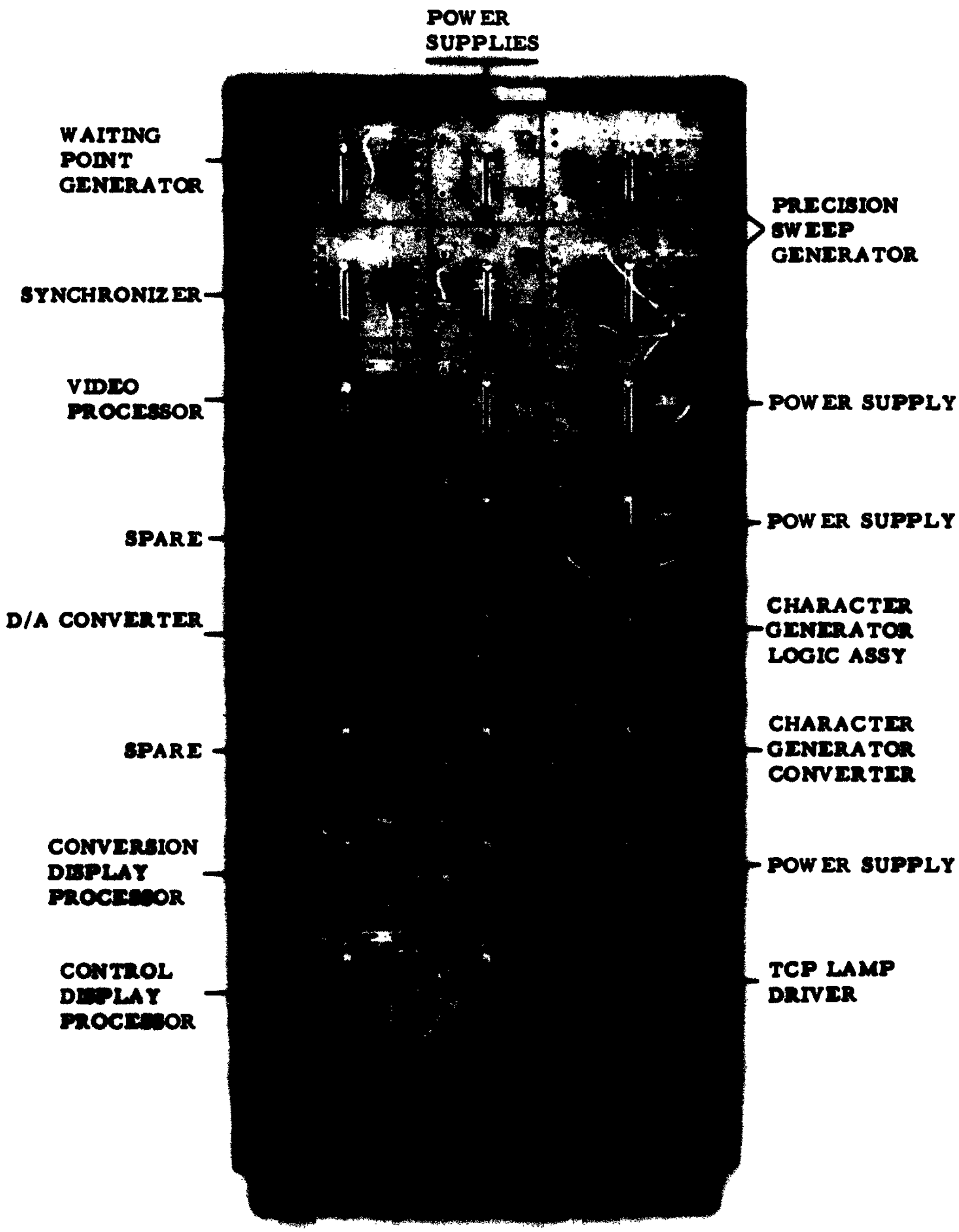


Figure 1. Conditioner-Generator Unit

or 3.0 microseconds prior to zero range time (beacon).

1.1.1.1.1.3 AZIMUTH DATA - The azimuth synchro data from the radar or beacon is 60-cps, 70 to 115-volt synchro data at one-speed or two-speed ratios of 1:1 and 1:10, 1:17 or 1:36. The antenna rotation rate is between 3 and 30 rpm. Reduced performance is to be expected at rates lower then 6 rpm.

1.1.1.1.1.4 SWEEP OUTPUTS - The precision sweep outputs to the Video Tracker Units and the PPD Displays must be resolved North-South and East-West Sweeps. The scale factor is five nautical miles per volt; East and North positive. The range must be at least 100 nautical miles. The sweeps must start at a voltage which may be adjusted ± 1 volt from 0 volts. The sweep length must be adjustable to provide sweep dead time of 10 percent of the sweep time plus 100 microseconds at high prf rates. The output impedance must be less than 1/2 ohm from dc to 3 kc. The sweeps must drive a load of 1000 ohms or more, shunted by 5000 uuf or less. The accuracy of the sweeps must be ± 0.05 mile ± 0.1 percent of the actual value.

1.1.1.1.1.5 SWEEP-ON GATE - A sweep-on gate must be provided with an on level between -1 and -3 volts for the duration of the sweeps and an off level between +0.1 volt and -0.1 volt, into a 75 ohm load. The rise and fall times must be less than 2 microseconds.

1.1.1.1.2 DESIGN ALTERNATIVES

1.1.1.1.2.1 WIDE-BAND RESOLVER - In this approach, a wide-band electromechanical resolver is driven by a servo system. A trigger from the radar or beacon initiates a fixed slope integrator to generate a range sweep. The range sweep is resolved intoCartesian coordinates in a wide-band sweep resolver which is driven by a two-speed servo system following the synchro transmitters of the radar or beacon set. The beginning of the resolved sweep is clamped to the antenna location voltage.

1.1.1.1.2.2 ZERO-AREA WAVEFORM - This technique is similar to that of the wide-band resolver. In the zero-area waveform technique, a range sweep of zero average area is generated by adding into the signal during dead time, a large pulse of polarity opposite to the sweep. After being resolved, the sweep need only be shifted to the antenna location.

1.1.1.1.2.3 **NARROW-BAND RESOLVER WITH SERVO SYSTEM** - An oscillator, narrow-band resolver, two demodulators and two variable sweep generators may be used in place of a wide-band sweep resolver. The servo system is the same as in the previous systems.

1.1.1.1.2.4 **DIGITAL ENCODER WITH SERVO SYSTEM** - The resolver is replaced by a sine-cosine shaft encoder. The outputs of the shaft encoder are fed to two digital to analog converters which, in turn, feed two variable sweep generators.

1.1.1.1.2.5 **RADAR-MOUNTED INCREMENTAL SHAFT ENCODER** - An incremental shaft encoder is mounted directly on the radar antenna. The information from the encoder is transmitted over narrow-band lines to the Video Tracking System site. It is then fed to two digital to analog converters and two variable sweep generators. This system eliminates the servomechanism.

1.1.1.1.2.6 **RADAR-MOUNTED SINE-COSINE SHAFT ENCODER** - A conventional sine-cosine shaft encoder is mounted on the radar antenna. The information from the encoder is transmitted over a wide-band link to the Video Tracking System site, where it is fed to digital to analog converters and variable-sweep generators. This also eliminates the servomechanism.

1.1.1.1.2.7 **OTHER TYPES OF SHAFT ENCODERS** - There are several types of magnetic shaft encoders which use a variable inductance as a parameter which is varied in a sinusoidal manner. One of these could be driven by a servo system or mounted on the radar antenna.

1.1.1.1.3 **FINAL DESIGN** (See figure 2)

1.1.1.1.3.1 **WIDE-BAND RESOLVER** - The wide-band resolver was selected as the most suitable design. This design is described in detail in paragraph 1.1.1.1.3.8.

1.1.1.1.3.2 **ZERO-AREA WAVEFORM** - The zero-area waveform method was rejected because with the dead time allowed, the compensating pulse would have been of such large voltage amplitude as to make transistor circuits unreliable.

1.1.1.1.3.3 **NARROW-BAND RESOLVER** - The narrow-band resolver was rejected because the transient response required for a wind-loaded antenna was

such that a very high carrier frequency with a very quickly responding demodulator would have been required. This would have resulted in excessive demodulator noise.

1.1.1.1.3.4 DIGITAL ENCODER AND SERVO - This alternative was rejected because it offered little more than the wide-band resolver in terms of accuracy, while costing considerably more.

1.1.1.1.3.5 RADAR-MOUNTED INCREMENTAL SHAFT ENCODER - The incremental shaft encoder was thought to be the best solution from an accuracy point of view. However, because of development costs for a suitable encoder and because of doubt as to whether the radar mount could be suitably modified in all cases, this alternative was rejected. It should still be considered for future applications.

1.1.1.1.3.6 RADAR-MOUNTED SINE-COSINE SHAFT ENCODER - This alternative was rejected because it offered no significant advantages over the incremental sine-cosine shaft encoder and would have been much more expensive because of the wide-band data link which would have been required.

1.1.1.1.3.7 OTHER SHAFT ENCODERS - These were rejected because of the doubtful state of development of the necessary encoding component.

1.1.1.1.3.8 DESCRIPTION OF FINAL DESIGN - The radar trigger is clipped to a constant amplitude and used to trigger a flip-flop (see figure 2). An output from the flip-flop starts a Miller integrator which generates a fixed-slope range sweep. The output of the range sweep generator is compared with an adjustable voltage. When it crosses this voltage, a reset pulse is generated which turns off the flip-flop and clamps the Miller integrator output to zero again.

The resulting range sweep is coupled to a resolver driver amplifier which drives the sweep into the wide-band resolver. The resolver amplifier also receives wide-band a-c feedback from a compensation winding on the resolver. Current in the primary winding of the resolver is sampled during sweep recovery time and is used to adjust the d-c output level of the resolver driver amplifier. This is done in such a manner that there is zero average d-c current and hence no magnetic saturation of the resolver.

The resolved sweep outputs of the resolver are fed to unity-gain operational amplifiers which drive the tracking system and the PPD Displays. A voltage is also fed to these amplifiers which cancels the average value of the sweep from the resolver and inserts the antenna location voltage for off-centering. This is done

by chopping between the base-line voltage of the a-c coupled sweep and the desired antenna location voltage during dead time with an electronic chopper.

The resolver is driven mechanically by a two-speed servo system at any one of three speed ratios as required. The servo amplifier is a 60-cps carrier amplifier throughout. It uses tachometer feedback for compensation. An offset voltage is added so that the position error may be adjusted to zero for any speed between 6 and 30 rpm. This offset voltage reduces the open-loop gain required of the amplifier but causes a position error when the servo system is stopped.

1. 1. 1. 1. 3. 9 MAJOR PROBLEMS AND SOLUTIONS

1. 1. 1. 1. 3. 9. 1 ACCURACY - In order to maintain the accuracy required of the sweep at all ranges, an extremely wide-band system is required. A very low-impedance resolver was necessary to obtain the desired system bandwidth of 0. 1 mc. This made the driving amplifier design extremely difficult, especially in maintaining the primary winding current at a zero average value. The usual method of doing this is to place a sampling resistor in series with the winding to measure the current. The current is then applied to a low-pass filter to remove variations which occur during a single sweep time. The resulting signal is used to adjust the d-c output of the resolver driver amplifier. This method was impractical because the very wide-band required in the primary forward channel resulted in impossibly long averaging times in the feedback path.

The solution of sampling the current at a critical point in the waveform was adopted. The sample data technique was used to prevent saturation of the resolver core. This technique provided the low drift required for the resolver driver amplifier. Considerable time was expended to find an output stage for the resolver driver amplifier having the necessary power output for the low impedance winding and a bandwidth sufficiently greater than 0. 3 mc to allow the overall a-c loop to be stable. A symmetrical push-pull circuit containing silicon power transistors was adopted.

1. 1. 1. 1. 3. 9. 2 DRIVE MOTOR - It was not possible to obtain a motor suitable for transistor drive in the servo system. This problem was solved by having a special motor made for the servo drive application.

1. 1. 1. 1. 3. 9. 3 RESOLVER - No standard resolver having both the required accuracy and the required bandwidth was available. Several resolvers of standard design were tested by the manufacturer and only those having the required bandwidth and accuracy (double the normally rated accuracy) were selected for this application.

1.1.1.1.3.9.4 SWEEP CLAMPING - A considerable problem was presented in clamping the resolved sweeps to the antenna location in the short dead time allowed. A synchronous dead-time chopper and feedback amplifier were finally adopted to solve this problem. The transistor chopper driving signals are obtained from the same gate signal which causes the range sweep to be generated.

1.1.1.1.3.9.5 EXCESSIVE LOADING OF SWEEP AMPLIFIERS - The sweeps are supplied to the Trackers and the PPDD systems via coaxial line in order to reduce noise pickup and permit the use of common-mode rejection circuits. This coaxial line results in a large capacitive load on the Precision Sweep Generator. Furthermore, it is necessary to drive this load by means of an amplifier with a bandwidth of approximately 0.3 mc. Careful compensation of the driving amplifiers and the use of very high frequency transistors and low impedance circuits throughout solved this problem.

1.1.1.1.3.9.6 TRIGGER CROSSTALK - Trigger crosstalk between the radar sweep generator and the beacon sweep generator caused some false triggering. This was because the 50-volt trigger pulse across a 75-ohm load constituted a very large amount of power dissipated in a very short time. This problem was solved by careful shielding and grounding techniques.

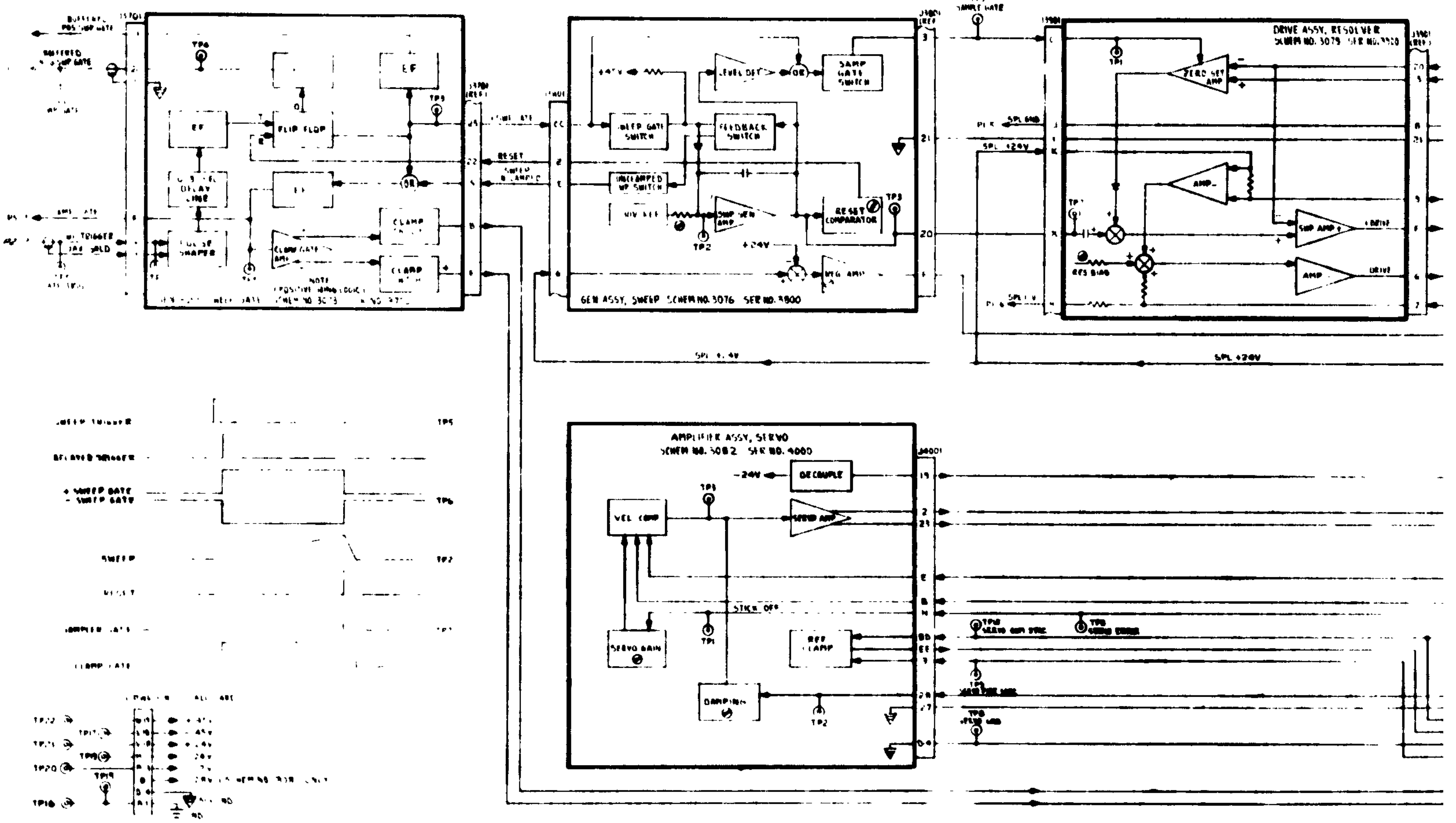
1.1.1.1.3.9.7 WEARING OF HIGH-SPEED GEARS - Some wear of the high-speed gears in the servo system was observed after a considerable operating time. This problem was solved by replacing one of the high-speed gears with a nylon gear.

1.1.1.1.4 RECOMMENDATIONS

1.1.1.1.4.1 GEAR RATIO - Under some conditions, it may be desirable to use a different type of servo amplifier. Where the gear ratio and the radar antenna rotation rate are such that the high speed synchro travels at a significant fraction of the synchronous speed, considerable difficulty is encountered with phase shift in the synchro signal. This can be partially overcome by using an amplifier which has an unfiltered, full-wave rectified power source for its output stages, thus eliminating out-of-phase signals. Attention should be paid in particular to methods of increasing the stability so that less tachometer compensation will be necessary and the servo system will have less following error due to changes in the antenna rotation speed.

1.1.1.1.4.2 DIGITAL PICKOFF - One possibility that should be considered is that of completely bypassing the servo system with a digital angle pickoff on the radar antenna.

1.1.1.1.4.3 **ADJUSTMENT OF RESOLVER CURRENT** - The sweep generator could be improved somewhat in its ability to quickly follow a large step in the prf. This is probably best done by incorporating a signal proportional to prf in the circuit which adjusts resolver current to compensate for prf. This signal could either be generated internally or could be obtained from the radar set.



DRIVE ASSY, RESOLVER
GEN ASSY, SWEEP SCHEM NO. 3076 SER NO. 3800
AMPLIFIER ASSY, SERVO
SCHEM NO. 3082 SER NO. 4000
FLIP FLOP
EF
CLAMP
FEEDBACK SWITCH
RESET COMPARATOR
SAMP GATE SWITCH
ZERO SET AMP
AMP
DRIVE
RESET
SPL +24V
DECOUPLE
VEL COMP
SERVO AMP
SERVO GAIN
REF CLAMP
DAMPING
STICK OFF
SWEEP TRIGGER
DELAYED TRIGGER
+ SWEEP GATE
- SWEEP GATE
SWEEP
CLAMP GATE

1

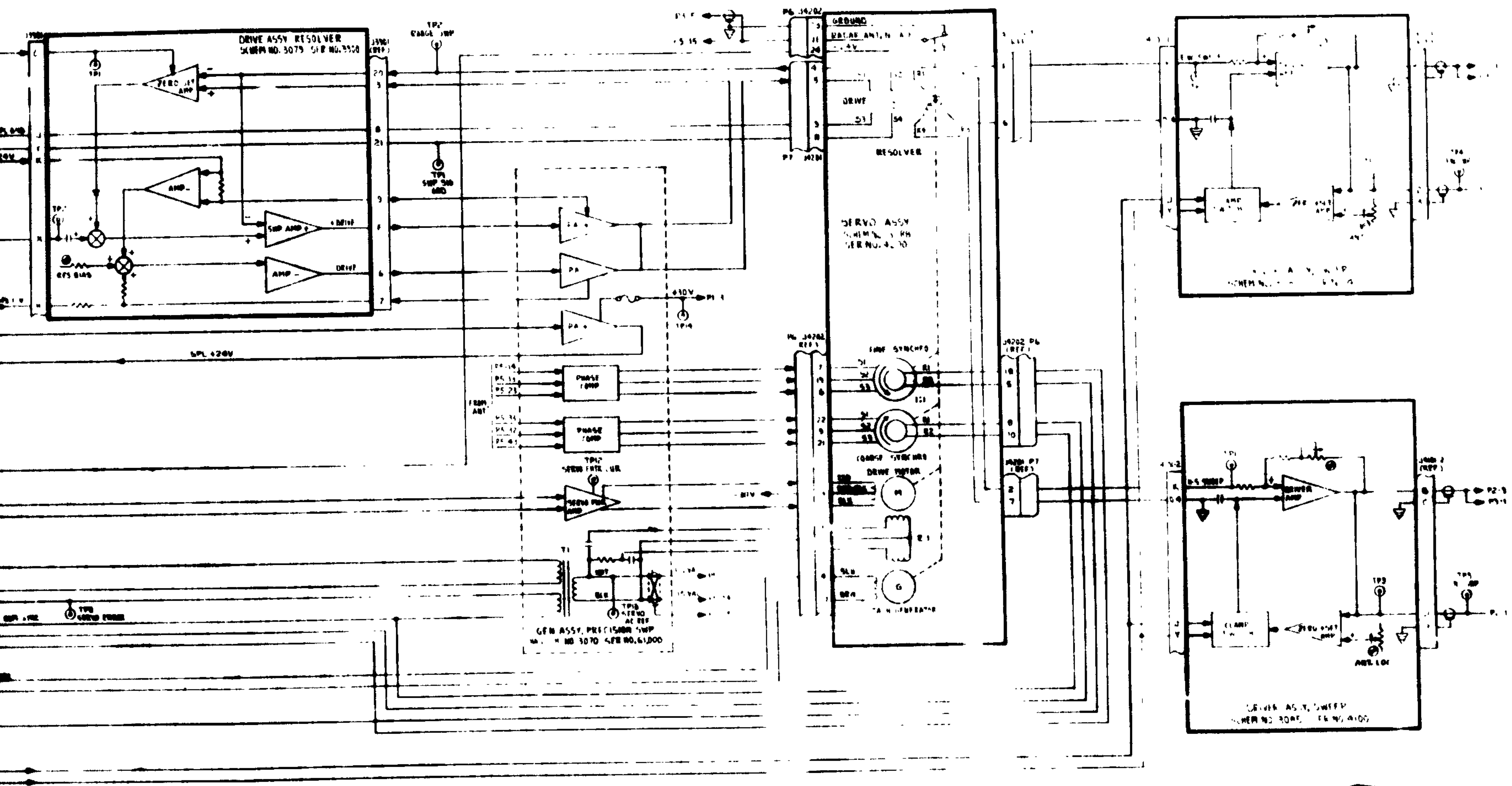


Figure 2. Precision Sweep Generator, Block Diagram

1.1.1.2 **WAITING POINT GENERATOR**

1.1.1.2.1 **DESIGN OBJECTIVES**

The Waiting Point Generator produces sixteen predetermined waiting points in the form of Tracker positioning voltages. These waiting point voltages are used for Tracker call-up positioning and are time shared among all the Trackers (one-pool or two-pool). The Waiting Point Generator also produces voltages which control both the slewing and manual tracking operations.

1.1.1.2.1.1 WAITING POINTS - The Trackers are to be called up to any of sixteen (originally eight) pre-established positions called waiting points. The waiting points are to be adjustable to any point within a 100-nautical mile radius of the radar. This is done to facilitate initial manual target acquisition by locating the waiting points near the expected points of entry of targets into the terminal area.

1.1.1.2.1.2 MANUAL CONTROL - Manual control of the Trackers must be provided in order to allow:

1. Initial acquisition of targets
2. Aiding of a Tracker which is normally in the automatic tracking mode
3. Completely manual tracking

1.1.1.2.2 **DESIGN ALTERNATIVES**

1.1.1.2.2.1 LOCATION OF WAITING POINTS - In locating the waiting points, there were two alternatives. Either the location of the waiting point could be stored digitally in the Video Track Programmer and decoded through a digital-to-analog converter, or the waiting point location could be stored in potentiometers which could be selected by electronic switches.

To move the Tracker to the waiting-point location, there are again two alternatives. Either the voltage representing the waiting point could be applied to the Tracker for a fixed length of time and the Tracker slewed in an open-loop fashion or the Tracker memory voltage could be slewed closed-loop to equal a waiting point voltage set by a potentiometer or digital-to-analog converter. In this connection, it should be remembered that the Tracker memory is an integrator and that applying a fixed voltage will cause the Tracker memory to move linearly until the voltage is removed.

1. 1. 1. 2. 2. 2 METHODS OF MANUAL CONTROL - There are many ways in which manual control of the Trackers can be accomplished.

The effect of the Slew Control Unit may be gross position control, incremental position control, rate control (where the Tracker moves at a rate proportional to the slew control motion or pressure), and finally, an additional velocity correcting capability commonly known as rate-aided slewing may be employed. Other considerations are proportional control versus non-linear control and two-speed control.

If velocity slewing rate-aided slewing is to be provided, there are again a number of possibilities. The velocity correction inserted into the Tracker may be directly proportional to the position correction, or it may be divided by the time since the Tracker was last corrected. Time may be either continuous or may be represented by a number of discrete steps, that is, divided by a series of constants; the particular constant being selected by the time since the Tracker was last corrected.

If velocity corrections (proportional to position correction divided by time since the Tracker was last corrected) are to be divided by continuous time, a method of division is necessary. Velocity correction may be generated by taking logarithms and antilogarithms, by the sum of squares method, by variable-sweep slope and sweep time circuits, or by a servo system divider.

Slewing of any Tracker in the pool is accomplished by any one of ten Slew Control Units. The switching may be accomplished electromechanically to tie the correct slew control to the correct Tracker continuously, or it may be accomplished by time sharing the ten Trackers with the ten Slew Control Units.

1. 1. 1. 2. 3 FINAL DESIGN (See figure 3)

1. 1. 1. 2. 3. 1 SETTING OF WAITING POINTS - Potentiometers were chosen as the method for setting the waiting points. This was done because of the ease of resetting the values of potentiometers. Initially, it was planned to use open-loop Tracker slewing because great accuracy was not required in absolute position of the waiting points. However, there was some doubt whether open-loop accuracy could insure that the character blocks would not overlap when several Trackers were called to the same waiting point. For this reason, it was finally decided to use closed-loop slewing. A fixed waiting-point slewing time is no longer required from the Video Track Programmer, only a minimum of 50 milliseconds.

1. 1. 1. 2. 3. 2 SLEW CONTROL - An incremental position type slew control was selected because this provides increased precision in manual Tracker correction. The high precision is desirable because it was decided to use velocity correction

type slewing (rate-aided slewing). Due to the use of waiting points, it will seldom be necessary to slew more than a few miles. Therefore, the slew control normally need not be able to slew the Tracker a great distance. However, for those rare occasions when greater distances are necessary, a two-speed arrangement is provided where a fast slew button may be depressed to increase the distance which one motion of the slew control will impart to the Tracker. Velocity corrected (rate-aided) slewing was essential to allow acquisition of high-speed targets. Targets above Mach 1 would be extremely difficult to acquire without this capability. In addition, rate-aided slewing facilitates completely manual tracking.

Proportional rather than non-linear control of the Tracker with the Slew Control Unit was adopted because of the ease of operation by the controller. Originally it was hoped that a velocity correction directly proportional to position correction could be used. However, as a result of a brief study undertaken with a tracking system available at Airborne Instruments Laboratory, this technique was rejected. Division by a series of constants rather than by continuous time was considered, as this was the technique employed in the Trackers used at Airborne Instruments Laboratory. The constants are determined by a mechanical or electrical stepping switch which is an unreliable and costly item in the system. A stepping switch would be required for each Tracker. Therefore, it was decided to employ a continuous time system where time would be remembered by an integrator in each Tracker. This presented the problem of carrying out an actual division of position correction by time-since-last-correction. Because time-sharing rather than electromechanical switching of controls was selected, as described below, a servo system divider was not practical, as it would have limited frequency response. The log and antilog type of divider was selected over the sum-of-squares method or the variable-sweep pickoff method because of the accuracy obtainable with the log-antilog and because considerable work had already been done on this technique in connection with the Analog Computer.

It was decided to use time sharing between the ten Slew Control Units and the waiting point signals, rather than electromechanical switching because of the considerable expense and unreliability of electromechanical switching. A stepping switch of fifty steps would have been required for each Slew Control Unit. There would also have been delay time while the stepping switch proceeded to the desired Tracker. Furthermore, a much greater number of wires would have been required between the Slew Control Units mounted in the PPDD's and the equipment room, compared with the number required with the time-sharing system.

1.1.1.2.3.3 <u>TIME SHARING</u> - In the final design (figure 3), it was arranged to use the same slewing lines to the Trackers for both waiting point slewing operations and manual slew control operations. The time sharing between the two is accomplished by the Video Track Programmer (VTP). The VTP interrupts the manual slew control sequence for fifty milliseconds or more to do a waiting point slew operation. The VTP selects the correct waiting point by activating one of the eight waiting-point select lines which connect the correct pair of waiting-point

potentiometers with electronic switches. Signals from the potentiometers or Slew Control Units are doubled in amplitude by an operational amplifier.

The signals are also switched so as to accomplish the normal and fast slew modes. During normal slew, the signals are maintained at zero reference, except during a short period of 100 microseconds.

During fast slew, the signals are at their actual slew voltage during the entire 1.6 millisecond section of the time-sharing sequence assigned to a particular Slew Control Unit. During waiting-point slew, electronic switches rearrange the amplifier scheme to compare the tracker output with the waiting-point potentiometers and to drive the difference to zero. In waiting-point slew, one of the amplifiers in each channel of the waiting point chassis is made open-loop to insure high gain in the overall loop that includes the Tracker.

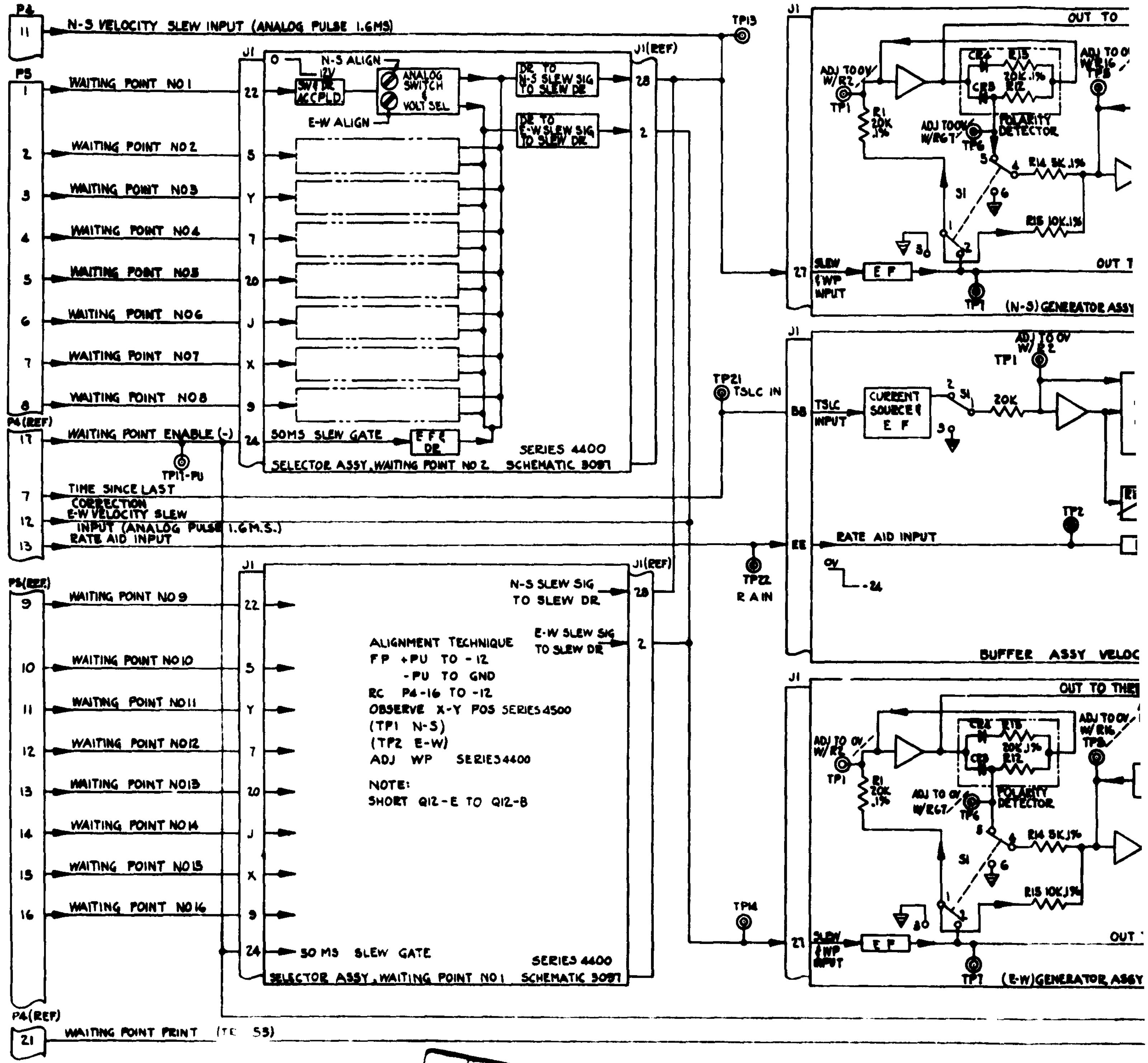
Position correction is fed to a log generator (one each for the North-South and East-West channels) in order to generate the velocity correction. A time-since-last-correction signal from the Trackers, time-shared in the same sequence, is also fed to a log generator. The log of time is then subtracted by operational amplifiers from the logarithms of the position slew signals. An antilog is taken of each of the differences which is then the velocity slew correction signal. This is fed to buffers and time-sharing circuits which provide for normal velocity slew as in normal position slew. There is no fast mode for velocity slew.

1.1.1.2.3.4 PROBLEMS - The major problem encountered in this design was in the operational amplifiers. Considerable difficulty was encountered in designing amplifiers which had adequate stability, adequate gain and adequate rise time for this application. The difficulty resulted, in part, from attempting to utilize an existing amplifier design developed for the Digital to Analog Converter.

1.1.1.2.3.5 ENGINEERING CHANGES - A second set of eight waiting points was added because of a change to GPL Specification 10000-523 to make a total of sixteen waiting points. This resulted in the addition of one more circuit card to the chassis. It was also required that waiting-point voltages be made available for printing on the PPD Displays without actually selecting a Tracker. This was accomplished by a rearrangement of the switching within the Waiting Point Generator.

1.1.1.2.4 RECOMMENDATIONS

1.1.1.2.4.1 HAND-OFF CAPABILITY - The Video Tracking System has the potential for automatic coordinate hand-off and automatic velocity hand-off. This hand-off can be from enroute to transition, from transition to transition, from


N-S VELOCITY SLEW INPUT (ANALOG PULSE 1.6MS)
WAITING POINT NO 1
WAITING POINT NO 2
WAITING POINT NO 3
WAITING POINT NO 4
WAITING POINT NO 5
WAITING POINT NO 6
WAITING POINT NO 7
WAITING POINT NO 8
WAITING POINT ENABLE (-)
TIME SINCE LAST CORRECTION
E-W VELOCITY SLEW INPUT (ANALOG PULSE 1.6M.S.)
RATE AID INPUT
N-S ALIGN
E-W ALIGN
ANALOG SWITCH
VOLT SEL
DR TO N-S SLEW SIG TO SLEW DR
DR TO E-W SLEW SIG TO SLEW DR
50MS SLEW GATE
SELECTOR ASSY, WAITING POINT NO 2
SERIES 4400 SCHEMATIC 3097
WAITING POINT NO 9
WAITING POINT NO 10
WAITING POINT NO 11
WAITING POINT NO 12
WAITING POINT NO 13
WAITING POINT NO 14
WAITING POINT NO 15
WAITING POINT NO 16
ALIGNMENT TECHNIQUE
FP +PU TO -12
-PU TO GND
RC P4-16 TO -12
OBSERVE X-Y POS SERIES 4500
(TP1 N-S)
(TP2 E-W)
ADJ WP SERIES 4400
NOTE:
SHORT Q12-E TO Q12-B
N-S SLEW SIG TO SLEW DR
E-W SLEW SIG TO SLEW DR
50 MS SLEW GATE
SELECTOR ASSY, WAITING POINT NO 1
SERIES 4400 SCHEMATIC 3097
WAITING POINT PRINT
TSLC IN
RAIN
CURRENT SOURCE & E F
RATE AID INPUT
BUFFER ASSY VELOC
(N-S) GENERATOR ASSY
(E-W) GENERATOR ASSY
POLARITY DETECTOR
SLEW & WP INPUT
OUT TO

1

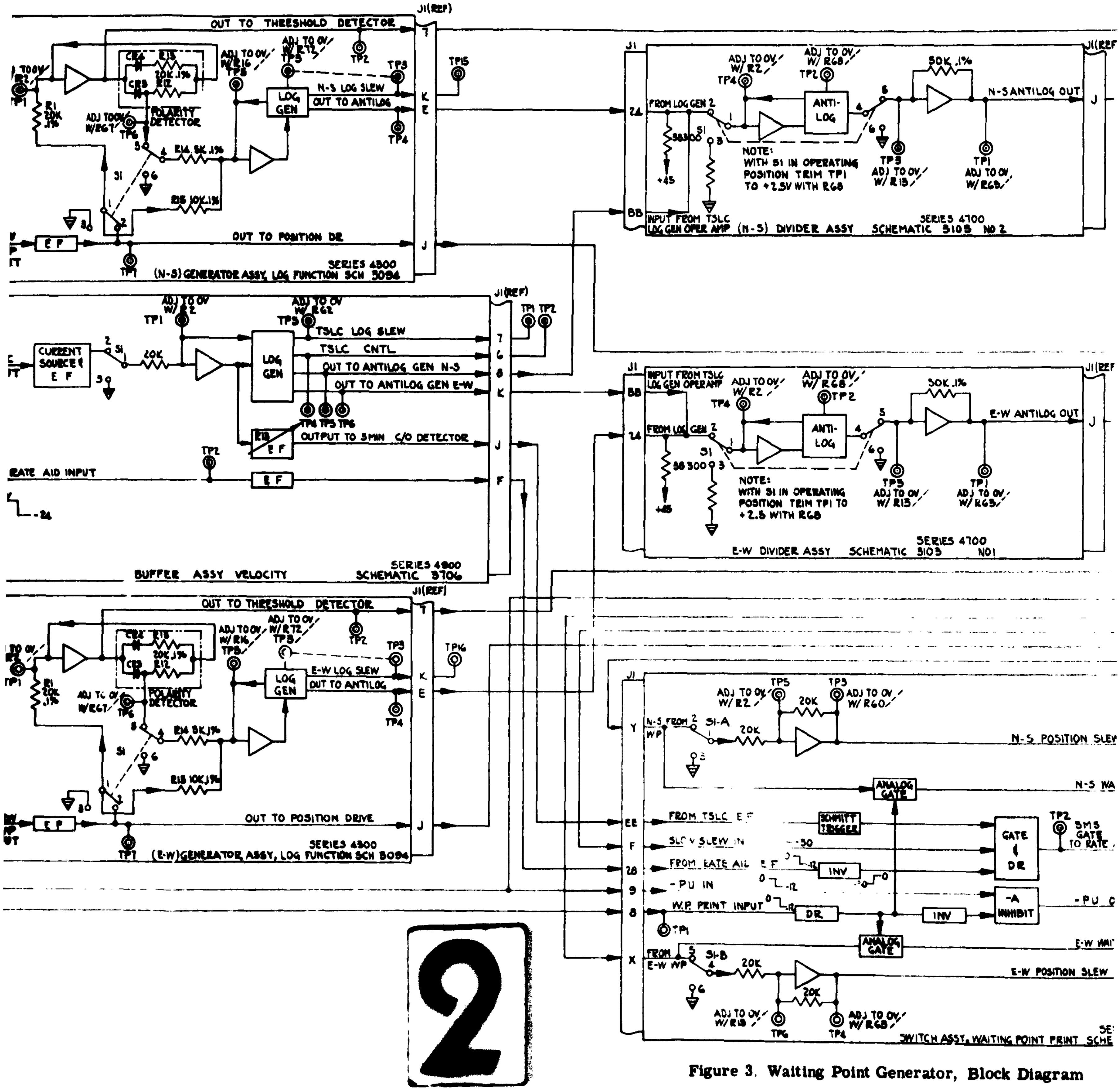
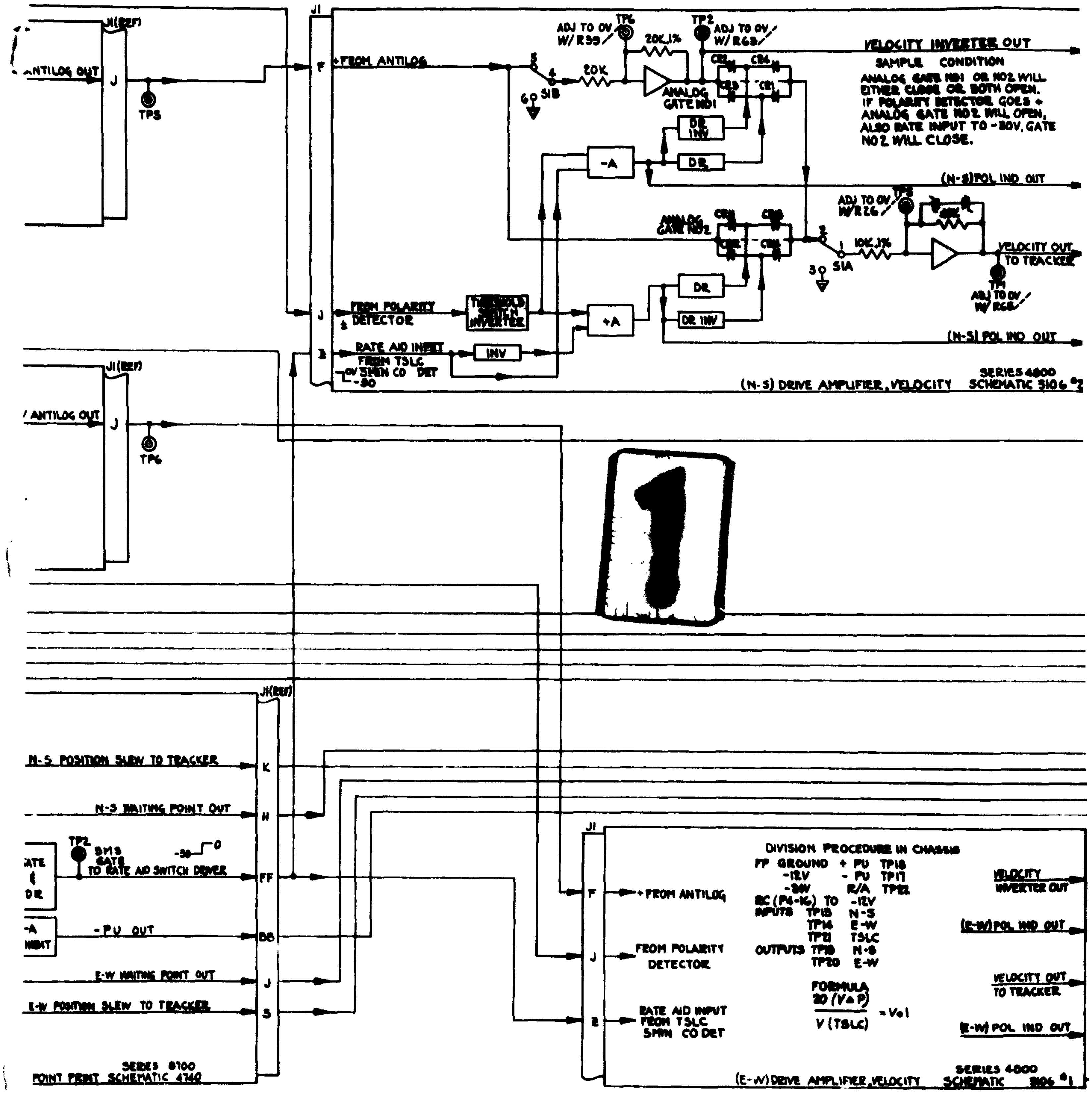


Figure 3. Waiting Point Generator, Block Diagram

Sheet 1 of 3



VELOCITY INVERTER OUT
SAMPLE CONDITION
ANALOG GATE NO1 OR NO2 WILL EITHER CLOSE OR BOTH OPEN. IF POLARITY DETECTOR GOES + ANALOG GATE NO2 WILL OPEN, ALSO RATE INPUT TO -30V, GATE NO2 WILL CLOSE.
(N-S) POL IND OUT
VELOCITY OUT TO TRACKER
(N-S) POL IND OUT
SERIES 4800
(N-S) DRIVE AMPLIFIER, VELOCITY SCHEMATIC 5106 #2
+FROM ANTILOG
FROM POLARITY DETECTOR
RATE AID INPUT FROM TSLC 5MIN CO DET
THRESHOLD SWITCH INVERTER
ANALOG GATE NO1
ANALOG GATE NO2
N-S POSITION SLEW TO TRACKER
N-S WAITING POINT OUT
5MS GATE TO RATE AID SWITCH DRIVER
-PU OUT
E-W WAITING POINT OUT
E-W POSITION SLEW TO TRACKER
SERIES 8100
POINT PRINT SCHEMATIC 4740
DIVISION PROCEDURE IN CHASSIS
FP GROUND + PU TP18
-12V - PU TP17
-30V R/A TP22
RC (P4-16) TO -12V
INPUTS TP13 N-S
TP14 E-W
TP21 TSLC
OUTPUTS TP19 N-S
TP20 E-W
FORMULA
20 (V∆P) / V (TSLC) = Vo1
VELOCITY INVERTER OUT
(E-W) POL IND OUT
VELOCITY OUT TO TRACKER
(E-W) POL IND OUT
SERIES 4800
(E-W) DRIVE AMPLIFIER, VELOCITY SCHEMATIC 5106 #1
1

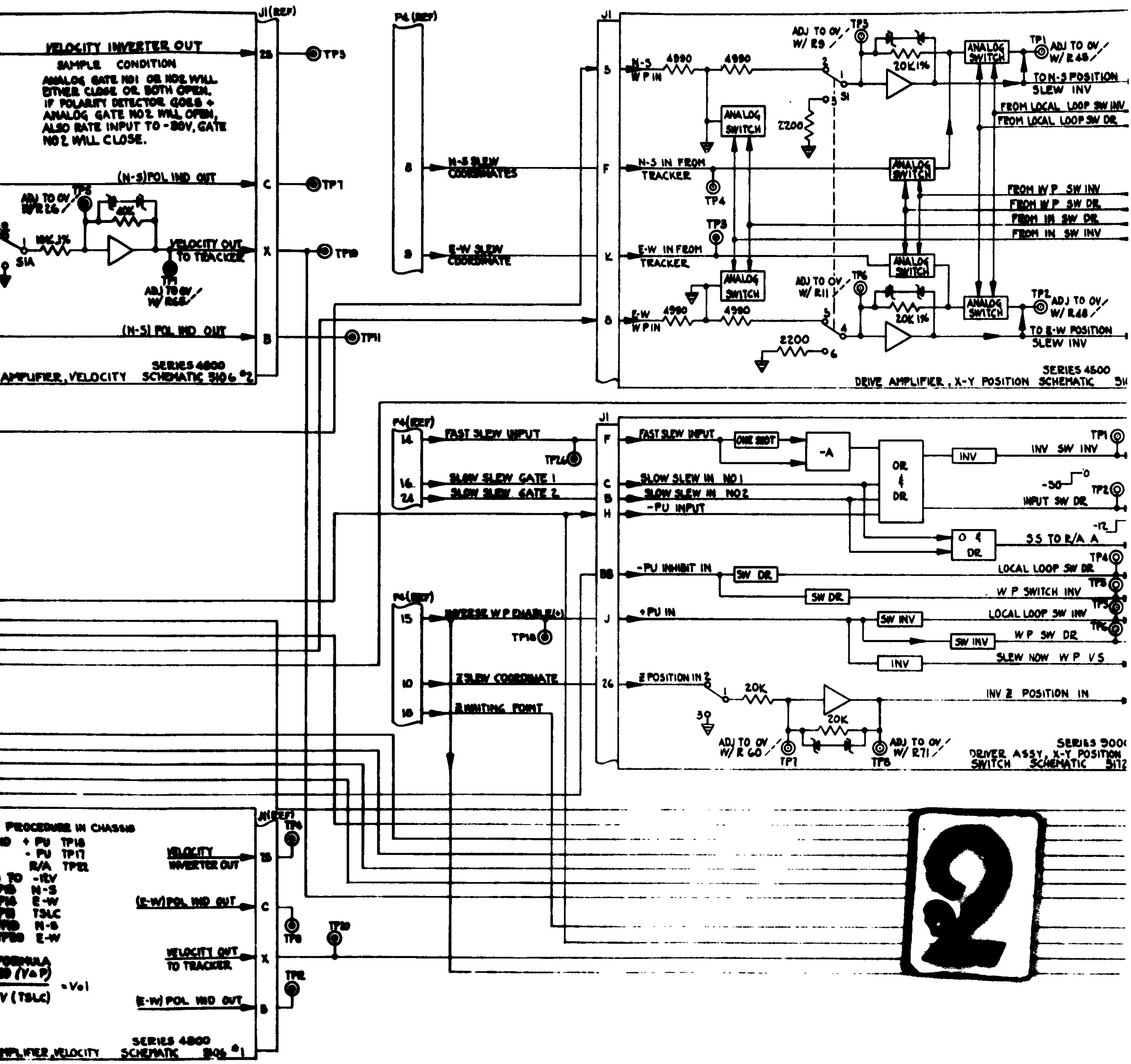
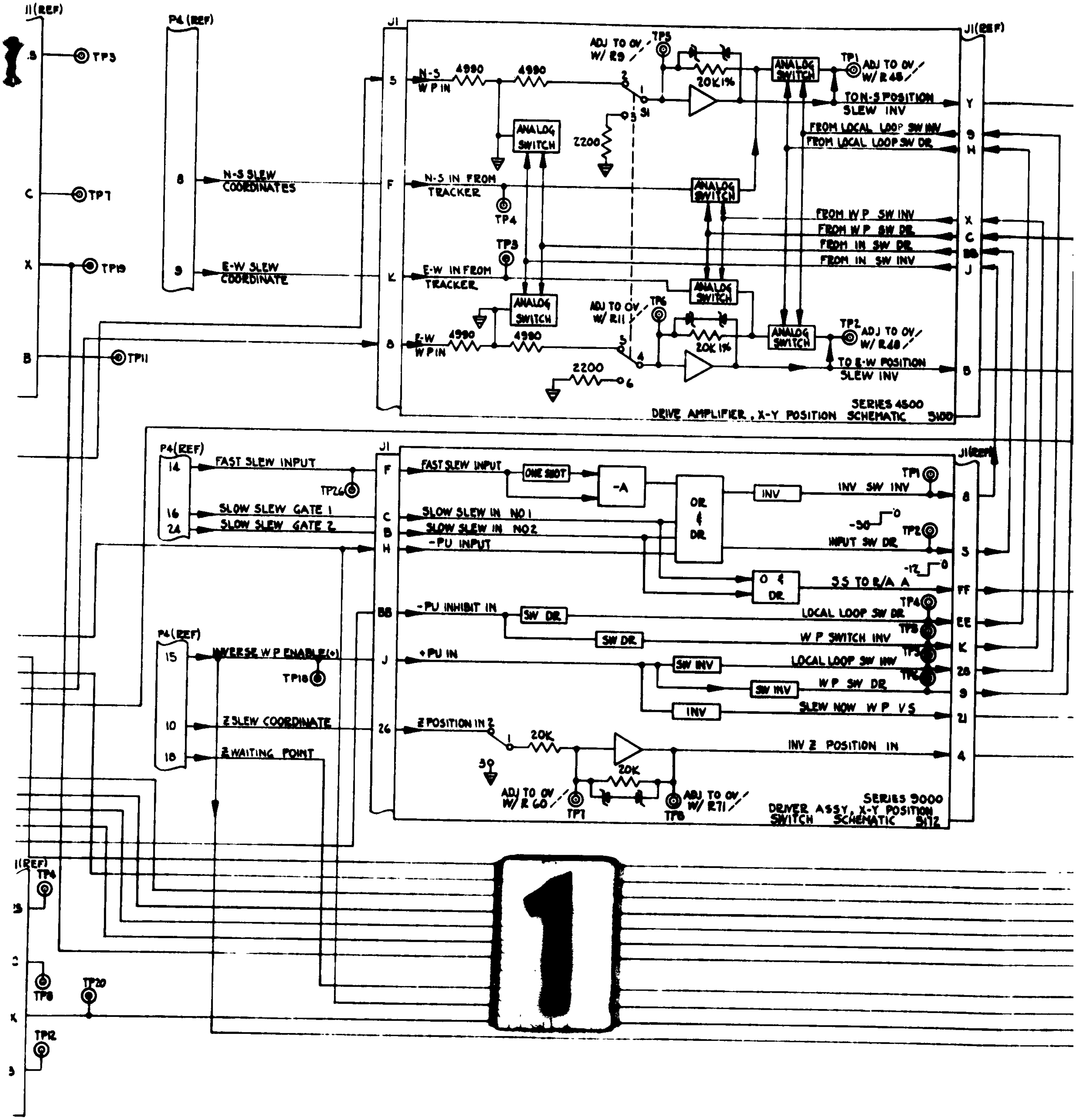


Figure 3. Waiting Point Generator, Block Diagram



J1(REF)
P4(REF)
J1
TP3
TP7
TP19
TP11
N-S SLEW COORDINATES
E-W SLEW COORDINATE
N-S W P IN
4990
ADJ TO 0V W/ R9
TP5
2200
S1
ANALOG SWITCH
20K 1%
TP1
ADJ TO 0V W/ R48
TO N-S POSITION SLEW INV
FROM LOCAL LOOP SW INV
FROM LOCAL LOOP SW DR
N-S IN FROM TRACKER
TP4
FROM W P SW INV
FROM W P SW DR
FROM IN SW DR
FROM IN SW INV
E-W IN FROM TRACKER
ADJ TO 0V W/ R11
TP6
TP2
ADJ TO 0V W/ R48
E-W W P IN
TO E-W POSITION SLEW INV
SERIES 4500
DRIVE AMPLIFIER, X-Y POSITION SCHEMATIC 5100
FAST SLEW INPUT
TP26
SLOW SLEW GATE 1
SLOW SLEW GATE 2
ONE SHOT
-A
OR & DR
INV
INV SW INV
SLOW SLEW IN NO 1
SLOW SLEW IN NO 2
-PU INPUT
INPUT SW DR
0 & DR
SS TO B/A A
-PU INHIBIT IN
SW DR
LOCAL LOOP SW DR
W P SWITCH INV
INVERSE W P ENABLE(+)
TP18
+PU IN
SW INV
LOCAL LOOP SW INV
W P SW DR
SLEW NOW W P VS
Z SLEW COORDINATE
Z WAITING POINT
Z POSITION IN
20K
INV Z POSITION IN
ADJ TO 0V W/ R60
ADJ TO 0V W/ R71
SERIES 9000
DRIVER ASSY, X-Y POSITION SWITCH SCHEMATIC 5112
TP20
TP12
1

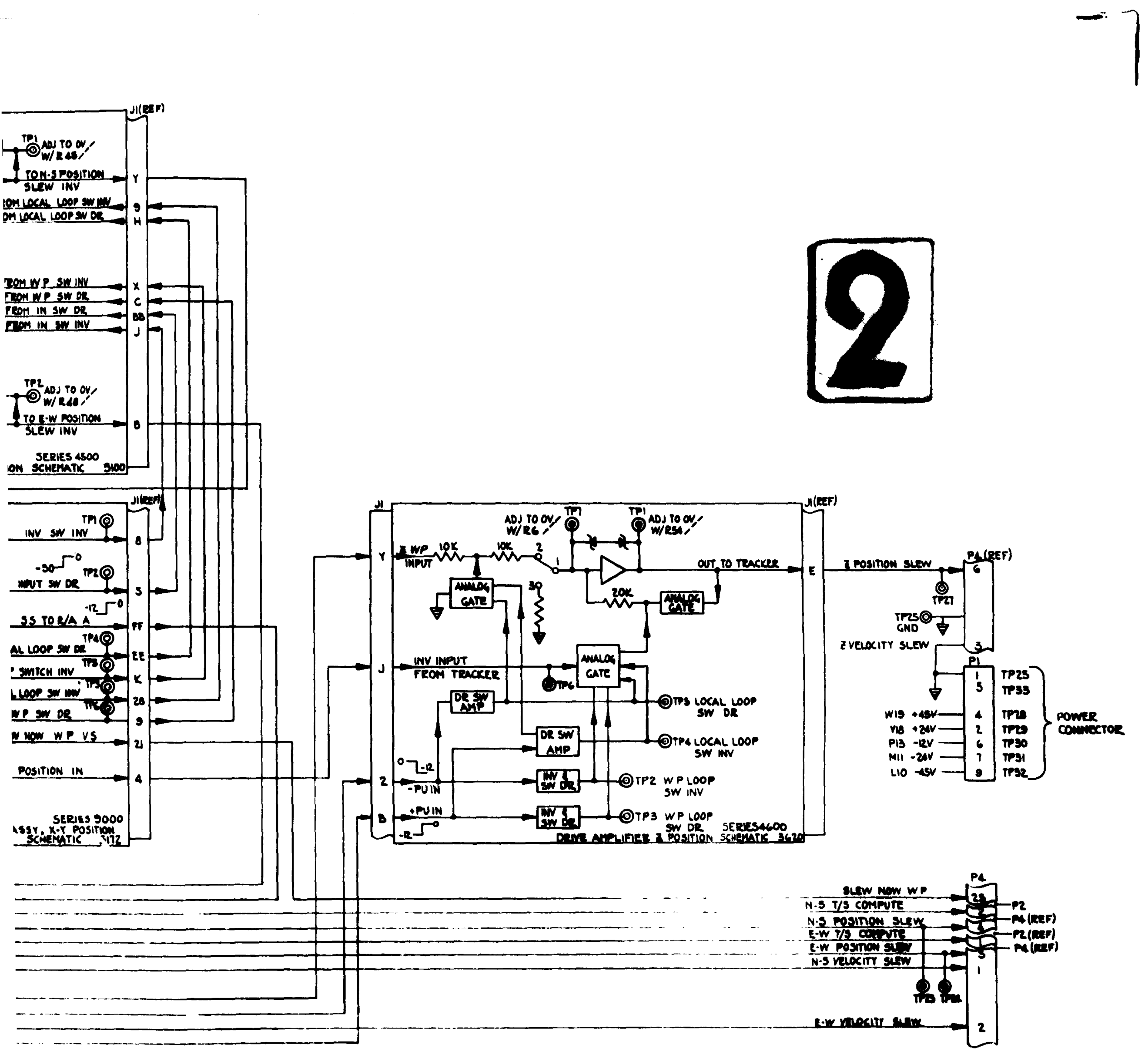


Figure 3. Waiting Point Generator, Block Diagram

Sheet 3 of 3

pool to pool, from operator to operator, and from terminal to tower. Additional digital circuits for the hand-off capability would most logically be incorporated in the Waiting Point Generator chassis if space were available. While this would eliminate most occasions for use of a waiting point, some waiting points would still be required. However, it may be desirable to employ the existing Digital to Analog Converter to produce the waiting point. This would eliminate the necessity for potentiometer settings and achieve more flexibility in programming the waiting points.

1.1.1.2.4.2 VELOCITY CORRECTION FOR POS + VEL SLEW - There are alternatives for computing the velocity correction when position plus velocity slewing is employed. Some of these may require fewer circuits than the log-antilog circuit now employed and they should be reviewed for that purpose.

1.1.1.2.4.3 NON-LINEARITY OF VELOCITY SLEW - Certain non-linearities occur in the present velocity function at slew signal extremes such as very short time-since-last-correction, very fast slew motion and very slow slew motion. These non-linearities should be reviewed from the human engineering point of view.

1.1.1.3 SYNCHRONIZER

1.1.1.3.1 DESIGN OBJECTIVES

1.1.1.3.1.1 BUFFERING - The Synchronizer must provide buffers where necessary between the Video Tracker Units and other equipment in the system.

1.1.1.3.1.2 OTHER FUNCTIONS - The Synchronizer must accomplish miscellaneous functions which cannot logically be assigned to any of the other assemblies with the Conditioner-Generator Unit as follows:

a. Gate-size signal generation

b. Schedule circle generation

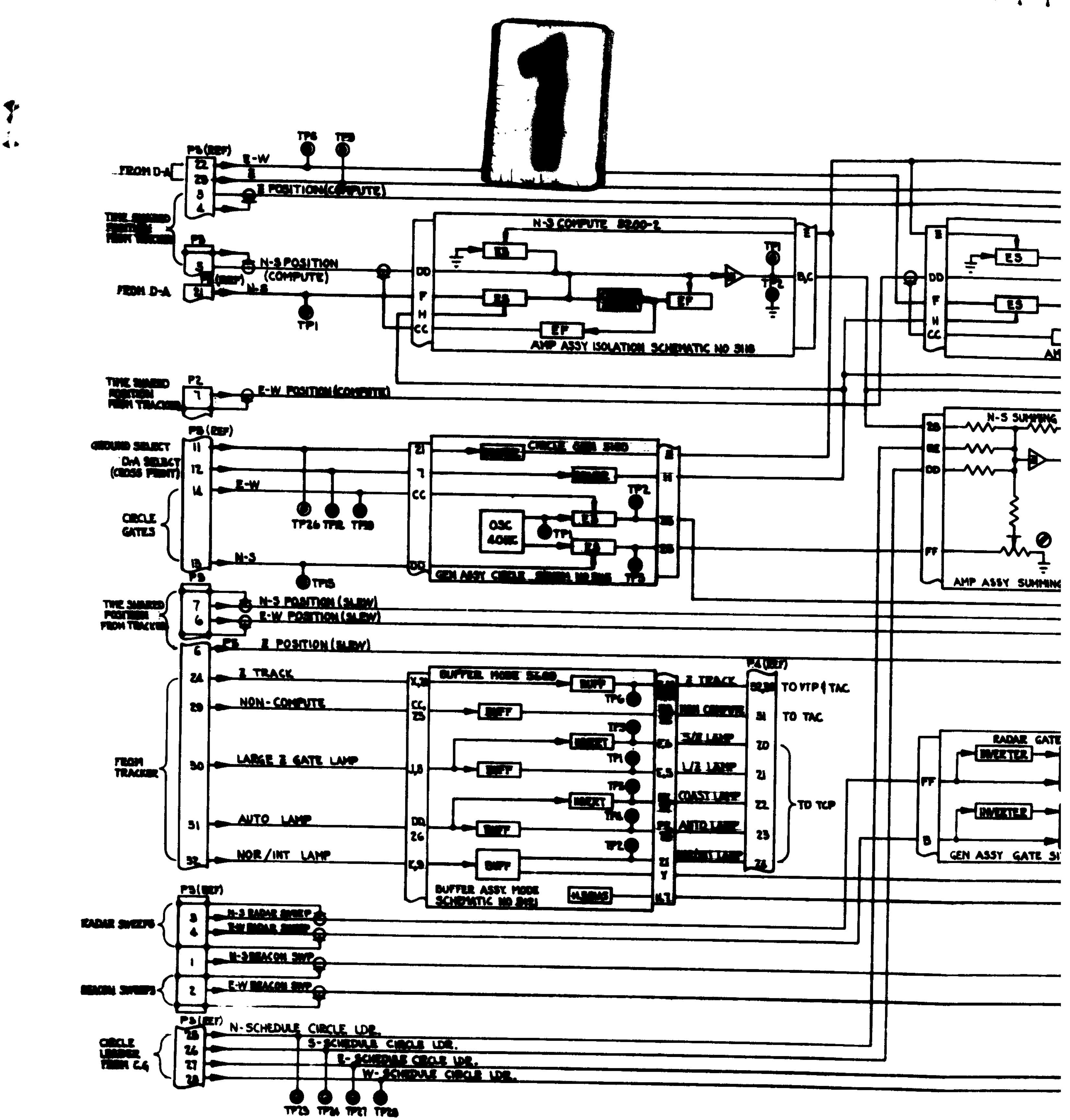
c. Summing of circle location, circle signal and circle leader voltages.

1.1.1.3.2 DESIGN ALTERNATIVES - The circuits are straightforward and there was very little in the way of significant design alternatives.

1.1.1.3.3 FINAL DESIGN

1.1.1.3.3.1 TRACKER OUTPUTS - There are six time-shared analog position outputs from the Tracker (see figure 4). They are North-South, East-West, and z (height) in the compute sequence and in the slew sequence. Because the output switches in the Tracker are of the 3-diode type, a current-source type load must be employed. Operation of the switches and the current sources is such that when a switch is turned on, the current through the source is equal to one-half of the total switch current.

Coaxial lines were used between the Trackers and the current sources in the Synchronizer to improve rise time and reduce noise. The shields are driven by a signal from the Synchronizer. After the current sources, the signals are buffered by amplifiers which feed them to the PPD Displays and the other equipments. The amplifiers have a small-signal bandwidth of approximately 0.3 mc and a linear rise time such that they will accomplish their full forty-volt swing in less than 100 microseconds. The drift of these amplifiers must be less than twenty millivolts per week. Five stages of amplification are used, with differential amplifiers in the first three stages. Careful frequency compensation results in stability even when driving a large capacitive load.



1
FROM D-A
TIME SHARED POSITION FROM TRACKER
Z POSITION (COMPUTE)
N-S POSITION (COMPUTE)
N-S COMPUTE
AMP ASSY ISOLATION SCHEMATIC NO
E-W POSITION (COMPUTE)
GROUND SELECT
D/A SELECT (CROSS POINT)
CIRCLE GATES
OSC 400KC
N-S POSITION (SLEW)
E-W POSITION (SLEW)
Z POSITION (SLEW)
Z TRACK
NON-COMPUTE
LARGE Z GATE LAMP
AUTO LAMP
NOR/INT LAMP
FROM TRACKER
BUFFER MODE
BUFFER ASSY MODE SCHEMATIC NO
TO VTP & TAC
TO TAC
TO TCP
RADAR SWEEPS
BEACON SWEEPS
N-S BEACON SWP
E-W BEACON SWP
CIRCLE LADDER FROM C.G.
N-SCHEDULE CIRCLE LDR.
S-SCHEDULE CIRCLE LDR.
E-SCHEDULE CIRCLE LDR.
W-SCHEDULE CIRCLE LDR.
N-S SUMMING
AMP ASSY SUMMING
RADAR GATE
INVERTER
GEN ASSY GATE

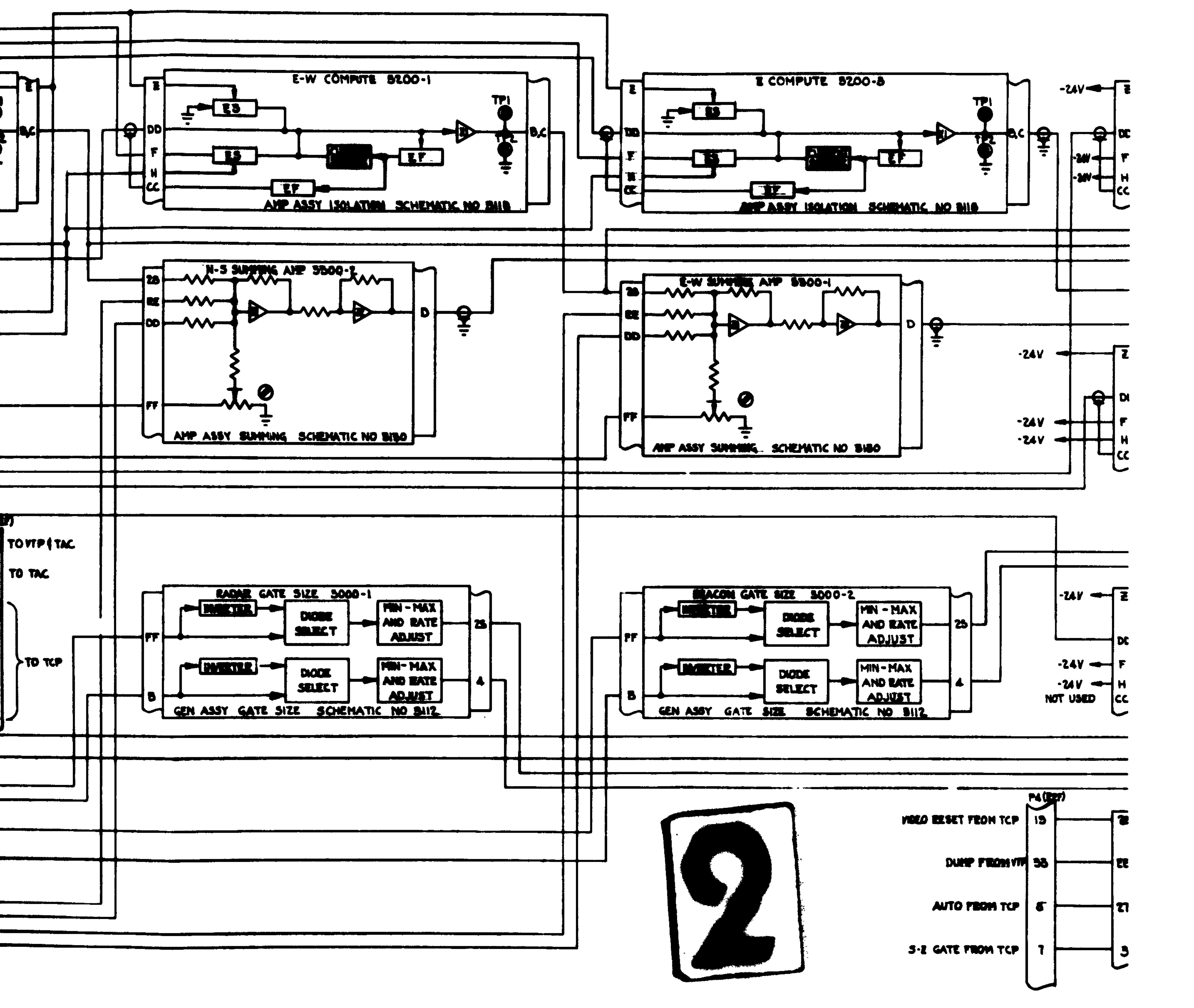
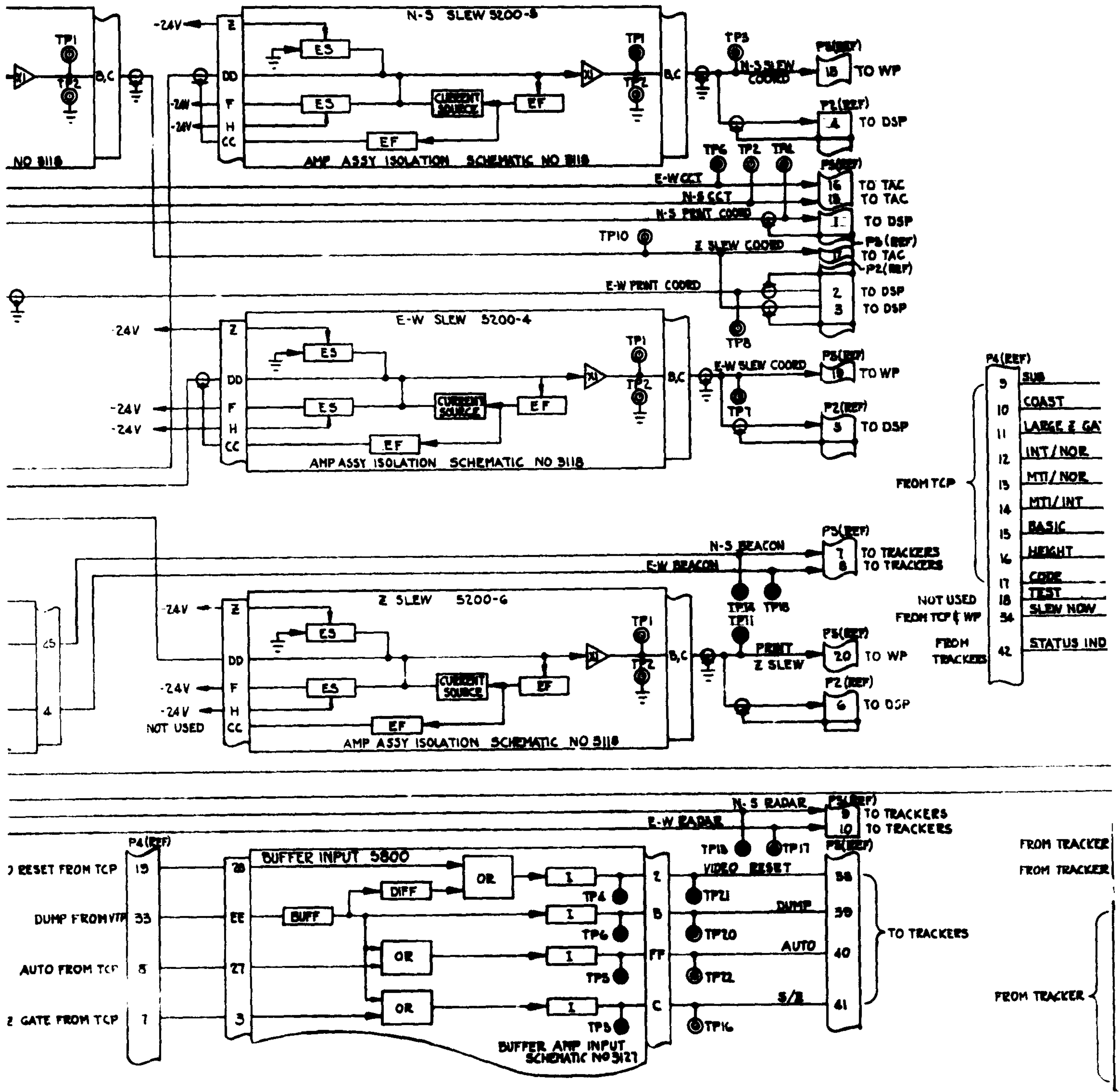


Figure 4. Synchronizer, Block Diagram

Sheet 1 of 2

[redacted]


N-S SLEW 5200-5
AMP ASSY ISOLATION SCHEMATIC NO 3118
NO 3118
E-W SLEW 5200-4
AMP ASSY ISOLATION SCHEMATIC NO 3118
Z SLEW 5200-6
AMP ASSY ISOLATION SCHEMATIC NO 3118
BUFFER INPUT 5800
BUFFER AMP INPUT SCHEMATIC NO 3127
ES
EF
CURRENT SOURCE
DIFF
BUFF
OR
-24V
NOT USED
N-S SLEW COORD
TO WP
TO DSP
E-W CCT
N-S CCT
N-S PRNT COORD
Z SLEW COORD
E-W PRNT COORD
TO TAC
E-W SLEW COORD
N-S BEACON
E-W BEACON
TO TRACKERS
PRINT Z SLEW
N-S RADAR
E-W RADAR
VIDEO RESET
DUMP
AUTO
TO TRACKERS
RESET FROM TCP
DUMP FROM VTP
AUTO FROM TCP
GATE FROM TCP
P4 (REF)
P5 (REF)
P2 (REF)
SUB
COAST
LARGE Z GA
INT/NOR
MTI/NOR
MTI/INT
BASIC
HEIGHT
CODE
TEST
SLEW NOW
STATUS IND
FROM TCP
NOT USED
FROM TCP & WP
FROM TRACKERS
FROM TRACKER

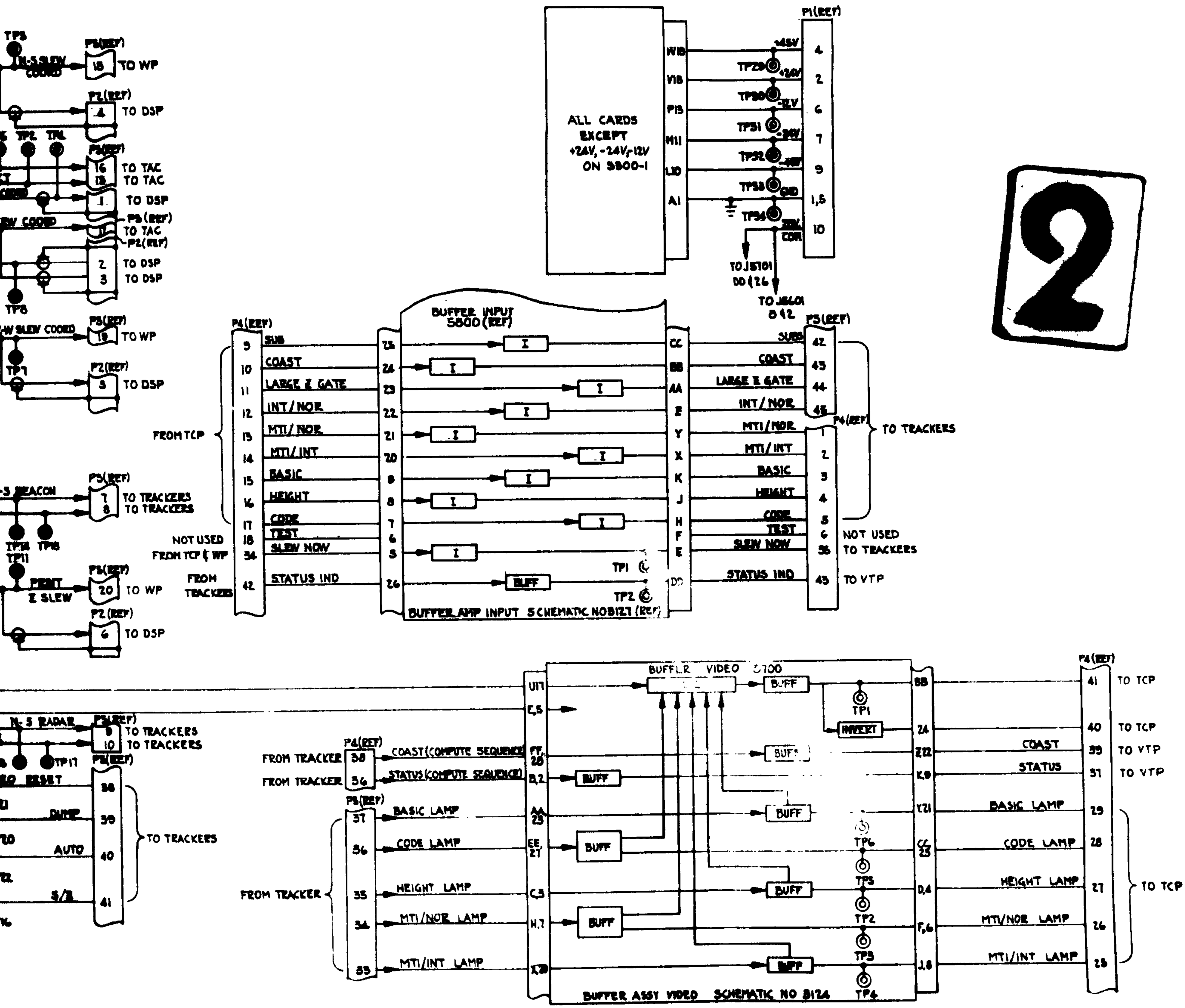


Figure 4. Synchronizer, Block Diagram

Sheet 2 of 2

1. 1. 1. 3. 3. 2 <u>CIRCLE AND CROSS GENERATION</u> - Schedule circles and crosses for the display are generated in the Synchronizer. A 40-kc, four-stage, phase-shift oscillator is used to gen rate signals. The North-South and East-West signals are picked off two stages apart, so that the two signals are 90 degrees out of phase. If both are added to the circle position at the same time, a circle results. If they are added sequentially, a cross results. The selection of one mode or the other is done by the Video Track Programmer. The addition of the cross or circle signals to the location voltage is done with operational summing amplifiers. Two amplifiers are necessary for each channel so that inversion does not occur in the overall system. The amplifiers also receive circle leader voltages from the Character Generator. Standard operational amplifier modules are used.

1. 1. 1. 3. 3. 3 <u>GATE SIZE VOLTAGES</u> - The four gate size voltages: North-South and East-West (radar and beacon) are generated in the Synchronizer. The output characteristics are determined by the tracking status of the Tracker. These voltages start at an adjustable level between plus ten volts and zero, which represents a minimum gate size of zero to two miles. A fraction of the absolute value of the radar or beacon sweep of the opposite coordinate is added to the gate-size voltage to expand the gate at right angles to its direction of displacement from the radar antenna. A maximum value is also provided for a gate size adjustable between zero and -10 volts which represents 2 to 4 miles.

1. 1. 1. 3. 3. 4 <u>BUFFERING</u> - Most of the logic signals to and from the Tracker are buffered in the Synchronizer. Buffering is necessary because system logic is all negative logic, while much of the Tracker logic is positive. Inverters of standard design are used. Additionally, many of the logical outputs drive lamp drivers which, in turn, light the correct lamps on Tracker Control Panels. A small amount of logic is provided to generate special pulses such as the reset signals, which are generated when a Tracker is dumped; and the Slew Mode Select Signal, which is generated when a new Tracker is selected.

1. 1. 1. 3. 4 <u>RECOMMENDATIONS</u>

1. 1. 1. 3. 4. 1 The Synchronizer serves as a buffer between the Tracker pool and other equipments. Modifications to the Synchronizer will therefore be contingent on modifications in other equipments from which its input and output requirements are derived.

1.1.1.4 VIDEO PROCESSOR

1.1.1.4.1 DESIGN OBJECTIVES - The Video Processor must perform the following operations:

a. Standardize and gate radar and beacon video for use by the Video Tracker Units.

b. Process radar and beacon altitude information as required for use by the Video Tracker Units.

c. Generate outlines from the radar and beacon tracking gates for display on the PPD Displays.

1.1.1.4.2 DESIGN ALTERNATIVES

1.1.1.4.2.1 PULSE STANDARDIZATION - The radar and beacon video can be standardized by use of any of several standard regenerative pulse generating circuits. These can be: a transformer-coupled blocking oscillator, a delay-line blocking oscillator, a one-shot multivibrator, or any of several other pulse generating circuits.

1.1.1.4.2.2 DISTRIBUTION OF VIDEO TO TRACKERS - The video pulses must be buffered to drive the Tracker pool. The Tracker pool may be connected so that all Trackers are in parallel and all receive the same video, or the pool may be broken into groups.

1.1.1.4.2.3 HEIGHT VIDEO - The processing of height video depends upon the characteristics of the radar and beacon signals available to the tracking system. Trackers require pulses at a scale of 20 volts ≈ 100,000 feet, with a gating pulse starting at least 1.9 microseconds before the associated video pulse.

1.1.1.4.3 FINAL DESIGN (See figure 5)

1.1.1.4.3.1 PULSE GENERATOR - After considerable experimentation, the transformer and delay-line blocking oscillators were rejected in favor of the one-shot multivibrator. The transformer-coupled blocking oscillator is difficult to design for a well defined pulse length which is not sensitive to temperature. For such a short pulse length, it is difficult to saturate the core so that it is necessary to depend upon transistor saturation. This results in temperature-dependent pulse width. A delay-line blocking oscillator was rejected because of the difficulty

in obtaining a sufficiently clean pulse shape with simple circuits. The one-shot provided a simple, reliable solution to the problem and it was therefore adopted.

1.1.1.4.3.2 DISTRIBUTION OF VIDEO - Each Tracker has a finite video input impedance and it was determined that fifty Trackers would present a combined impedance small enough compared to the 75-ohm impedance of the line to cause reflections. Therefore, the Tracker pool was split into two halves and each half driven separately.

1.1.1.4.3.3 HEIGHT VIDEO - During the first two years of the program, there was considerable doubt about the form of the radar and beacon altitude signals which would be available to the Trackers. It was finally determined that the two signals would have approximately the same form, and that this would be a pulse at a scale of 10 volts equal 100,000 feet, with a starting time at least two microseconds before the start of the associated video pulse. In the case of overlapping targets, the beacon would provide a pulse corresponding to the target at shortest range, except that when exact coincidence occurred, no pulse would occur. The 3-D radar decoder would alternate the two targets on successive main bangs. It was necessary to design an amplifier which would multiply the amplitude of these pulses by two and buffer them to the Video Tracking System on coaxial lines. This meant that a large capacitance had to be driven. A one-stage amplifier was designed to carry out this operation. The amplifier is of the feedback type with two feedback loops, one to set the gain accurately, the other to set the base line accurately at zero. The amplifier was given a 75-ohm output impedance to match the line. This prevents multiple reflection, as the receiver end of the line is not terminated. A one-stage amplifier was used, as this resulted in a frequency-stable amplifier with very good rise time. Since the gain is not exactly predictable, a vernier gain control has been incorporated.

1.1.1.4.3.4 GATE OUTLINES - The gate outlines are generated in a straightforward manner by differentiation of the tracking gates and summing of the positive and negative pulses. A buffer drives the pulses to the PPD Displays on a 75-ohm line.

1.1.1.4.3.5 ENGINEERING CHANGES

1.1.1.4.3.5.1 RANGE SWITCHING - Range switching of the video inputs in pairs between MTI and Normal, MTI and Integrated, and Normal and Integrated was incorporated in compliance with a change in GPL Specification 10000-523. The range at which the switching occurs is independent for each of the three pairs and is set by adjusting a one-shot multivibrator.

1.1.1.4.3.5.2 DYNAMIC VIDEO STANDARDIZATION - Automatic variation of threshold for the radar videos was incorporated. This is known as Dynamic Video Standardization in this system. The standardization was provided primarily to compensate for changes in radar i-f amplifier gain. Since the operation will be very dependent upon the type of radar used, no attempt was made to check this circuit thoroughly. It may be that the circuit will have to be tailored to the individual situation at the site.

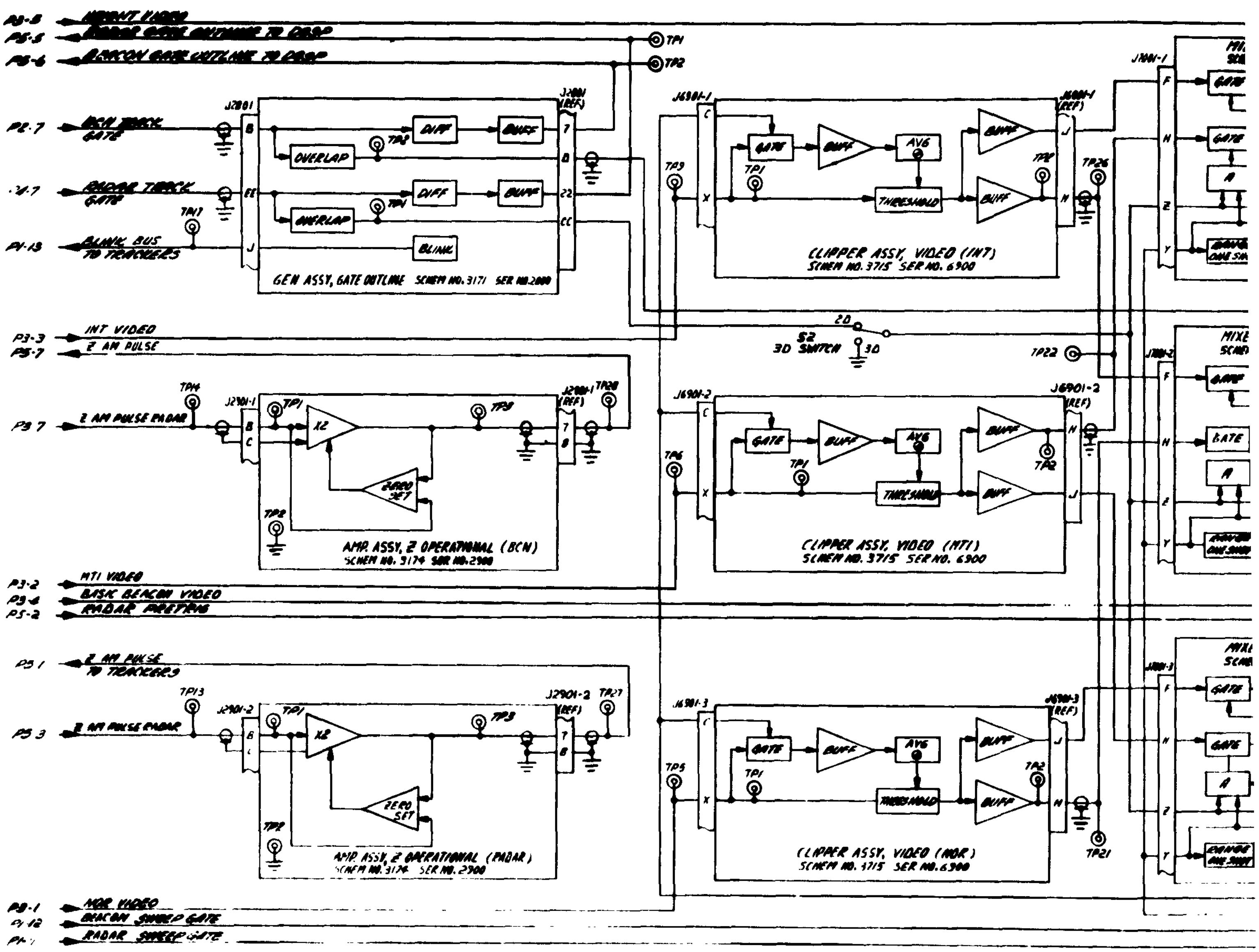
1.1.1.4.3.5.3 GATE OVERLAP BLANKING - Gate overlap blanking was incorporated. This causes radar video and basic beacon video to be blanked whenever two tracking gates overlap. This results in automatic coast of the two Trackers involved. Provision was made for disabling this feature for radar video when 3-D radar is used.

1.1.1.4.3.5.4 SWEEP ORIGIN BLANKING - A circuit was incorporated to blank both radar and beacon videos near the sweep origin. This was done to insure coasting of the Tracker when the target is directly over the antenna. The blanking range is adjustable between one and five miles.

1.1.1.4.3.5.5 PRETRIGGER ADJUSTMENT - GPL Specification 10000-523 was revised to specify adjustment of the radar pretrigger from 3 to 55 microseconds. A precision delay consisting of a fixed sweep generator and precision pickoff were incorporated to fulfill this requirement.

1.1.1.4.4 RECOMMENDATIONS

1.1.1.4.4.1 IMPROVED AGC - An improved agc system would be of considerable value to the video processing and video tracking equipments. The present dynamic video standardization employs an open-loop technique of limited effectiveness. An agc system should be tailored to the radar set with which it operates. In this case, however, it was necessary to devise a generalized agc system. At the time when a particular radar set is selected for operation of the Video Tracking Group and the PPD Display, the agc should be modified accordingly. An agc signal from the Video Processor, or possibly from the Tracker could be fed back to the radar set to vary the i-f gain rather than the video threshold level.



HEIGHT VIDEO
RADAR GATE OUTLINE TO DRDP
BEACON GATE OUTLINE TO DRDP
BCN TRACK GATE
RADAR TRACK GATE
BLANK BUS TO TRACKERS
OVERLAP
DIFF
BUFF
BLINK
GEN ASSY, GATE OUTLINE SCHEM NO. 3171 SER NO. 2800
GATE
AVG
THRESHOLD
CLIPPER ASSY, VIDEO (INT) SCHEM NO. 3715 SER NO. 6900
INT VIDEO
Z AM PULSE
S2
3D SWITCH
Z AM PULSE RADAR
ZERO SET
AMP. ASSY, Z OPERATIONAL (BCN) SCHEM NO. 3174 SER NO. 2900
CLIPPER ASSY, VIDEO (MTI) SCHEM NO. 3715 SER NO. 6900
MTI VIDEO
BASIC BEACON VIDEO
RADAR PRETRIG
Z AM PULSE TO TRACKERS
AMP. ASSY, Z OPERATIONAL (RADAR) SCHEM NO. 3174 SER NO. 2900
CLIPPER ASSY, VIDEO (NOR) SCHEM NO. 4715 SER NO. 6900
NOR VIDEO
BEACON SWEEP GATE
RADAR SWEEP GATE

1

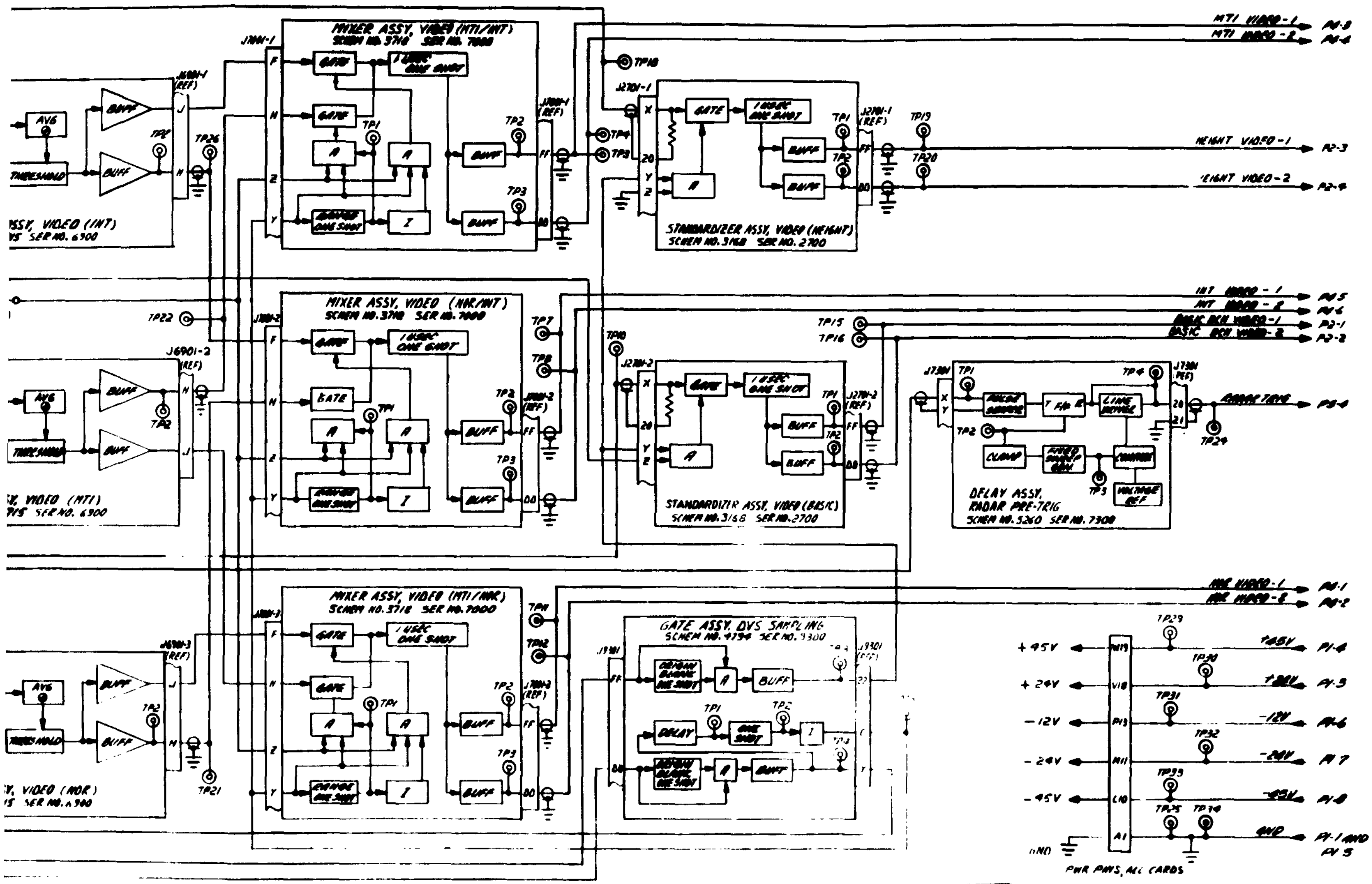


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Figure 5. Video Processor, Block Diagram

1. 1. 2 CHARACTER GENERATOR

1. 1. 2. 1 DESIGN OBJECTIVES

The Character Generator must receive signals from the Video Track Programmer, Video Tracking System, and PPD Display System. It must generate the intensity pulses, analog voltages and timing signals to select one of the 10 display consoles and to effect properly positioned, 19-character identity tags, ID (identity) leaders and bars, circles, crosses and 19- or six-character special display messages.

1. 1. 2. 1. 1 INPUT DATA - The Character Generator unit must accept display messages in bit serial form, and timing signals from the Video Track Programmer. It must convert these into such analog voltages, gates and pulses as are needed to select and position characters and other information on the PPD Displays.

1. 1. 2. 1. 2 OUTPUT DATA - The Character Generator Unit is primarily a digital-to-analog converter which provides analog voltages for selection and/or generation and positioning of characters (utilizing the Typotron character matrix) and other Lissajous waveforms to be displayed in the PPDD console. It must generate, from the timing signals, leaders to associate tracking-gate print data and position circles with tracking gate outlines on the displays, along with sweep and print gates for controlling the displays. The Character Generator also must generate those timing and intensity signals and pulses as required for this function.

1. 1. 2. 1. 3 PARITY CHECK - Each character must be checked for parity before printing. In the case of a character showing wrong parity, a question mark must be printed in its place. Printing of characters in a line must be from west to east and printing from line to line must be from north to south.

1. 1. 2. 1. 4 SPECIAL DISPLAYS - The Character Generator Unit must cause special displays to appear periodically or on a controller callup basis at prescribed locations on displays. Special displays are to be used for landing sequence, missed approach and scramble and return-to-base corridors. In addition, a schedule cross display must be generated to show the position of up to five landing sequence slots on prescribed missed-approach routes.

1. 1. 2. 1. 5 MODE B CIRCLE DISPLAYS - The Character Generator must send the necessary control signals to the PPD Display system so that it will

cause Mode B position circles, their associated leaders, and missed approach schedule crosses to be printed once each antenna scan interval.

Internally generated in the Character Generator are leader sweeps for both the ID format (ID tag) and the schedule circle. A bar sweep must be generated to indicate manual or automatic track mode of operation. Intensifying gates and a special focus change gate (for changing the PPD Display from radar to character-write focusing) must also be generated. The Character Generator must provide 19 characters for display in the ID tag and 19 or 6 characters for display in the special display mode of operation.

The Character Generator also must provide analog outputs and timing gates to the Video Conditioner equipment, with which to position schedule circles and timing signals for their generation.

1. 1. 2. 2 DESIGN ALTERNATIVES

1. 1. 2. 2. 1 INPUT DATA - The input data to the Character Generator could have been included in the digital message such that no analog signals or gates were required. The digital message could be either bit serial - character serial, or bit parallel - character serial. These techniques require an excessive number of circuits in the Character Generator and would partially duplicate operations of the Video Track Programmer. The input message could also be a combination of bit serial - character serial with gates and analog signals as required. This technique minimizes the number of circuits in the Character Generator and Video Track Programmer but increases the complexity of troubleshooting and remoting of the Character Generator.

1. 1. 2. 2. 2 OFFSET (ID) LEADER - The leader may be generated by using variable-slope sawtooth generators which are clamped at a predetermined time or by using fixed-slope generators which are clamped at predetermined voltages. The variable-slope sawtooth generator simplifies the leader intensity pulse circuit but requires different writing speeds, depending on the direction of the leader. The fixed-sweep-rate sawtooth generator will result in a leader which may contain a dog leg. This occurs when the x clamp voltage is not identical to the y clamp voltage.

1. 1. 2. 2. 3 CIRCLE LEADERS - The circle leader sweep voltage requires different clamp levels as a function of the distance between the tracker coordinate and the computed aircraft coordinate. The accuracy of clamping the leader can be achieved by using either diode clamp circuits or transistor clamp circuits. Also the sweep voltages can be generated at a scale factor of unity or a scale factor of 5 to 1 with respect to the .33 volt per microsecond scale factor required

on the output of the print coordinate bus. The scale factor of 5 to 1 would result in less noise as caused by the sweep generator circuits on the print coordinate line.

1.1.2.2.4 ANALOG POSITION AND INCREMENTAL VOLTAGES - The scale factor of these voltages may be unity with respect to the GPL required voltages or they may be at a scale factor of 3 to 1. The output impedance of the operational amplifiers which drive these lines may be near zero ohms impedance or at an impedance level of 93 ohms. In the initial design, because of the progress of other equipment designs, it was not possible to deviate from the GPL requirements of unity gain amplifiers and near zero ohm output impedance.

1.1.2.3 FINAL DESIGN (See figure 6)

The Character Generator is used for printing of characters on the PPD Display tube during the following three methods of operation:

a. Tracker And Waiting Point Print - These displays consist of an offset leader, bar and 19 character format.

b. Special Displays - These are character groups which are located in a blanked-off region of the bright display tube. The position of this display is determined by East-West and North-South call-up position voltages. The character groups are centered about the position voltages and spaced according to a fixed plan by group-shift voltages which are produced by the Character Generator. The character groups may have six characters as in landing sequence (LS) and miss d approach (MA) displays, or there may be groups of 19 characters as in the return-to-base and scramble-corridor displays. In these displays, 3 of the 19 characters may be blanked so that 16-character groups appear.

c. Crosses And Circles - Crosses are printed to represent empty schedule boxes on the PPDD and the Character Generator supplies an eastward going leader with two characters which give the landing sequence number of the empty schedule box. In Mode B, circles are also printed to represent scheduled aircraft positions. The Character Generator supplies circle leaders which connect the tracking gate with the associated schedule circle.

1.1.2.3.1 PHYSICAL CONFIGURATION - The Character Generator consists of two chassis; the Logic Chassis and the Converter Chassis. The Logic Chassis receives signals from the Video Track Programmer (VTP) and PPDD and processes the signals for use by the Converter Chassis. The Converter Chassis receives control signals from the VTP and from the Logic Chassis, D/A Converter, and PPDD. It utilizes these signals to control the PPDD displays and the Synchronizer during the character printing operations.

1.1.2.3.2 TRACKER AND WAITING-POINT PRINT - The following operations are performed in order to present leaders, bars, and 19-character groups on the PPD Display:

a. A system reset (pulse) resets the parity flip-flop and the VTP sends an offset code, a TCP-Select code, and print control data in parallel form to the Character Generator. The Special Display signal is false ($\bar{X}$ is true) and the 19:6 Matrix Select signal (S) is true. These signals remain in these states during the entire 19-character print-up.

b. The TCP select code is decoded by a matrix. One of ten buffers on the driver matrix card, 3030, selects the console upon which the leader, bar, and 19-character group are to be printed. Settling time is allowed before the system reset pulse occurs, in order to allow the beam to settle at the Tracker coordinates which appear on the print coordinate busses at the display.

c. Offset Trigger No. 1 sets an offset flip-flop which is not reset by the system reset pulse until the end of the print-up. The output of this flip-flop, the leader gate signal, is sent from the Logic chassis to the offset leader generation circuits in the Converter chassis. On the offset leader card, 3058, the leader gate signal allows an integrator to generate a ramp. The ramp is clamped to an adjustable voltage which determines the distance which separates the character group from the Tracker. The output of the integrator is coupled to an inverting amplifier so that both positive and negative going sweeps are available.

Both positive and negative sweeps start, clamp, and reset simultaneously. The offset code is processed by the offset select matrix card 3066, which allows codes 0 through 7 to select any one of eight offset leader directions. Switches at the output of the integrator and inverting amplifier connect positive or negative leaders to the N-S and E-W offset and incremental cards, 5747, to generate a leader in the correct direction. For example, a N-W leader would require a negative going sweep connected to the N-S offset and incremental summing amplifier and a positive going sweep connected to the E-W offset and incremental summing amplifier. The offset and incremental amplifiers are inverting amplifiers. The offset and incremental bus voltage thus starts from zero and rises on a ramp with a slope of 0.025 volt per microsecond and with the polarity required for the correct direction of the offset leader. When the ramp reaches an adjustable reference level, it is clamped. The clamped voltage remains constant during the rest of printing of the 19-character group. Character-shift (incremental) voltages are added to the clamped reference voltage to position each character of the 19-character group at a location which is offset from the tracker position on the display. The distance from the tracking gate is determined by the leader clamping voltage in the Character Generator, and the direction of the offset is determined by the operator at each display through the TCP, VTP and offset select code.

The leader intensity pulse is also initiated at the first offset trigger pulse. The leader gate starts a multivibrator which generates a pulse whose width is less

than the time required for the leader to clamp. Only the first part of the leader is illuminated, so that it does not write through the character group.

Print control data from the Video Track Programmer is used on the leader and bar intensity card, 3027, to determine the type of leader as follows:

Normal	$\overline{AB}$
Bright	$A\overline{B}$
Serrated	$\overline{A}B$

If a normal leader is called for, the pulse is gated to a normal amplitude amplifier. If a bright leader is called for, the pulse is gated to a bright amplifier. Both amplifiers are connected to the same leader intensity pulse coaxial cable. If a serrated leader is called for, the pulse goes to the bright amplifier and a 120-kc multivibrator starts. This multivibrator blanks the leader pulse for approximately four out of every eight microseconds.

d. Offset Trigger No. 2 sets the bar flip-flop which is connected as a one-shot multivibrator. This flip-flop sends a 100-microsecond bar gate signal to the Converter Chassis. The beam is swept Eastward by an integrator on the bar generator card, 5763, which is started and reset by the bar gate signal. A feed-back clamp across the integrator prevents hangup. The bar gate signal also adds a step to the N-S offset and incremental amplifier so that the bar appears above the character group. The output of the integrator is connected to the E-W offset and incremental amplifier to write the bar from left to right across the top of the character group. The bar gate signal initiates one out of three possible operations on the leader and bar intensity card, 3027, according to the print-control data code:

1. Starts a full-bar ($\overline{C}D$)
2. Starts a half-bar ($C\overline{D}$)
3. Starts neither multivibrator ($\overline{CD}$)

The print control data code thus determines the type of bar presentation: full bar, half bar or no bar at all. A pulse from the bar or half-bar multivibrator is gated into the normal amplifier and fed to the PPDD on the leader intensity pulse coaxial line.

e. During the second character time of the bar, the display message from the VTP enters the shift register which is associated with the logic assembly B circuit card, 3282. The message is in serial form and is shifted through the register by clock pulses. At the end of the last bit, after the bar has been completed, the first transfer reset pulse occurs. The transfer reset pulse transfers the first character of the message, in parallel, from the shift register to the intermediate storage (IS) register (associated with the IS logic assembly card, 3018) if parity is good. If parity is not good, the intermediate storage

register receives a code for printing a question mark.

Each character consists of eight bits: 3 bits for the x select and compensation voltage, 3 bits for the y select and compensation voltage, and a parity-check bit which makes the sum of the ones odd for each character. No clock pulse occurs during the eighth bit, which is a space used for operations controlled by transfer reset pulses. A parity flip-flop counts the number of ones in each character. This flip-flop is true when the transfer reset pulse occurs, provided that the parity count is odd.

The parity flip-flop is reset by the system reset pulse at the start of the message and by transfer reset pulses which are delayed two microseconds and reshaped on the parity generator card, 3024.

The intermediate storage register flip-flops are connected to weighting resistors on the D/A select and compensation assembly circuit card, 5737. The output of the select and compensation amplifiers is biased at -17. 5 volts and rises in 5-volt increments, according to the weighting resistors which are connected to the input of the amplifier by the Intermediate Storage Register. The output voltages from the select and compensation amplifiers are sent to the display where they move the beam to the correct spot on the character matrix inside the display tube. The matrix shapes the beam to the required character shape. The process of shifting the message through the shift register and transferring it one character at a time to the intermediate storage register, which controls the select and compensation amplifiers, is repeated 19 times, once for each character. The intermediate storage register holds each character after transfer reset, until the next character is loaded into it. Thus, the select and compensation amplifiers remain at voltages corresponding to the previous character of the 19-character group, until the next character occurs. The first transfer reset pulse also resets the spot-character flip-flop. The output of this flip-flop is buffered on the circle print generator card, 3294, and sent to the PPDD to change the focus of the cathode-ray tube, allowing the wide beam to be shaped by the matrix. The spot character flip-flop is reset by a system reset pulse one character after the last transfer reset pulse occurs, allowing the display tube to use the radar writing beam.

The transfer reset pulses which are associated with the Logic Assembly A card, 3036, advance a counter in order to position characters correctly in the 19-character format. The counter that is driven by the logic A card switches weighting resistors on the offset and incremental assembly which add shift voltages to the clamped offset leader voltage. Shift voltages on the offset and incremental busses deflect the beam from one character position to the next. The counter starts in position No. 10 is at the end of the offset leader. The first transfer reset pulse advances the counter to position 1, moving the beam to the first character position at the upper left-hand corner of the 19-character matrix. Succeeding transfer reset pulses advance the counter so that characters are written left to right, line by line, until character No. 19 is printed at the lower-right corner of the format. A system reset pulse then resets the counter to position 10.

Transfer reset pulses control the character intensity pulses. They are gated and buffered and used to trigger a delay multivibrator which, in turn, starts a width multivibrator on the character print pulse card, 3060. The delay allows amplifiers to settle after the transient at each character shift voltage. The width multivibrator partially controls the brightness of characters. There are two ways in which character intensity pulses may be inhibited:

1. A TSU blanks signal is formed by an AND gate at the shift-register output. This signal gates transfer reset pulses on drum input amplifier card, 3051, in the Logic chassis if the VTP sends a display message character which commands the printing of a blank.

2. "Line Select In" signals from the display which is being printed upon and AND gated with outputs from the counter flip-flops generates the line gate. This is accomplished on the drum input amplifier card. Thus, the line gate signal from the Logic chassis can inhibit intensity pulses in the Converter chassis (on character print pulse generator card, 3060) when the counter positions the beam to the line which the operator has selected to be blanked, so that characters will not appear in those lines.

Characters are not blanked in the presence of either the special display signal or offset code 31 (cross print) from the VTP. These signals are AND gated with the inhibiting signals described above.

f. The system reset pulse which occurs at the end of the character after the last transfer reset pulse resets the parity, offset, spot-character, and counter flip-flops. The offset and incremental bus thus returns to zero volts, the beam moves back to the tracker location on the print coordinate bus, and the beam is focused again for radar spot writing. The Character Generator is now ready for whatever operation is next called for by the VTP.

1.1.2.3.3 <u>SPECIAL DISPLAYS</u> - The Video Track Programmer sends a special display signal (x is true) and a TCP select code to the Character Generator unit. Call-up position voltages are buffered on the call-up assembly circuit card, 5820. Switches at the output of the amplifiers on this card are enabled so that the call-up voltages are added to the offset and incremental amplifiers. This is done in order to offset the special displays into the blanked area of the display tube. Offset codes 9 through 26 are processed by offset matrix card, 3066, and group shift decoder card, 5755. The latter connects the proper weighting resistors to the offset and incremental amplifiers in order to position the special display group at the correct location, offset from the center of the blanked-off area. The center is determined by the call-up voltages.

Since no leader or bar is needed in sepcial displays, the offset trigger pulses are not sent by the VTP. However, the display message is loaded into the shift register and intermediate storage register, and characters are selected by the select and compensation busses in the same manner as described above.

If 19-character groups are to be printed (the last three of the first line may be blank), the 19:6 matrix select (S) is true. If 6-character groups are to be printed, the 19:6 matrix select is false ($\overline{S}$ is true). This signal from the VTP modifies the logic of the counter in which the shift voltages are generated. This counter is associated with the logic assembly A circuit card, 3036.

When the VTP sends an override call-up gate, it is buffered on character print pulse generator card, 3060, and sent to the PPDD in order to print immediately. In normal operation, a counter in the PPDD counts down print cycles. For example, it allows data to be printed only during every fourth print cycle of the VTP instead of during every print cycle. The override call-up gate bypasses this counter and allows immediate printup.

1.1.2.3.4 CROSSES - In Missed Approach operation, crosses are printed on the display in empty schedule boxes by request of the operator. The Character Generator adds to the cross an east leader and two characters, in order to identify the landing sequence number of the schedule box.

The VTP sends data to the Character Generator in the same form as a Tracker message. Since no bar is required, offset trigger No. 2 is absent. Offset code 31 is sent to select an East-going leader and to modify the logic of the counter which generates the shift voltages. The two characters are therefore printed on the same line as the East-going leader, instead of one line above. Generation of the circle display pulse is described below.

1.1.2.3.5 MODE B CIRCLES - Mode B circles do not utilize the character printing circuits in the Character Generator. The offset and incremental and the select and compensation busses are not used while printing Mode B circles which show scheduled aircraft position.

The Character Generator selects the consoles and provides leaders from the Tracker gate to the circle. Rapid printup of circles and circle leaders is accomplished by bypassing the print cycle counter in the display for three seconds after every antenna rotation.

A three-second timer on circle print card, 3294, is actuated once every antenna rotation by an antenna north gate signal in the Radar Precision Sweep Generator. The timer consists of a bistable circuit which is set by the antenna north gate. The output of the bistable circuit starts a three-second ramp. At the end of three seconds, the ramp resets the bistable circuit. The bistable circuit output holds a second bistable circuit in the reset position except for the three seconds after each antenna north gate. The leading and trailing edges of the "circle pulse in" signal are differentiated, and set and reset the second bistable circuit. The output of the second bistable circuit is buffered and sent to the PPDD to bypass the print cycle counter during the three seconds after each antenna north gate.

Thus, the beam cannot write streaks across the display tube if the antenna north gate signal occurs in the middle of a circle pulse in signal, since the second bistable circuit can be set only at the leading edge of the circle pulse in signal.

The circle pulse in signal also drives switches which parallel the feedback resistors of the offset and incremental amplifiers during circle printups. Since the offset and incremental bus voltage is added to the print coordinate bus voltage at the display, the offset and incremental bus must be at zero potential in order for the circle location to be correct. The select and compensation busses remain at voltages which correspond to the last character printed.

The leading edge of the circle pulse in signal is delayed 30 microseconds by a multivibrator on circle print card, 3294. The resulting pulse enables circle leaders on the circle leader generator card, 3291. North and South circle leaders and East and West circle leaders are generated by r-c networks and are clamped to the N-S difference voltage and E-W difference voltage respectively. These voltages determine the circle leader length in the x and y directions. The polarity of the difference voltage determines the polarity of the leaders, so that two of the four leaders which are sent to the Synchronizer remain at zero volts. All four circle leaders are summed with the Tracker voltage to write a leader from the Tracker gate to the circle location. Since the x and y components of the circle location with respect to the tracker may be different, one leader may clamp before the other. The circle leader may thus dogleg.

The delayed circle pulse is AND gated with the circle leader unclamped signal, which is true until both circle leaders have been clamped, to form the circle leader intensity pulse which is buffered on the character print pulse card, 3060, and sent to the PPDD. The circle leader intensity pulse starts with the circle leader 30 microseconds after the leading edge of the circle pulse in signal and ends within 56 microseconds, when both circle leaders have been clamped.

The circle is generated when the VTP enables switches at the output of an oscillator in the Synchronizer. After the circle leaders clamp, sine-wave voltages from the oscillator are added to the Tracker and clamped circle leader voltages on the print coordinate bus. At the same time, the circle intensity pulse in signal from the VTP is buffered on character print pulse card, 3060, and sent to the display.

1.1.2.3.6 ENGINEERING CHANGES - The Character Generator, as originally designed, was the first equipment to be delivered. During the interval between Character Generator layout and delivery of this equipment, many additions were required. For example, ID leader, bar, special display position voltages, and 19 or 6 count capability. As a result of these additions, the equipment was not reliable and contained an excessive number of controls. A redesign of the Character Generator was requested in order to minimize controls and increase the reliability of the equipment. This was accomplished to bring the Character Generator to its present configuration.

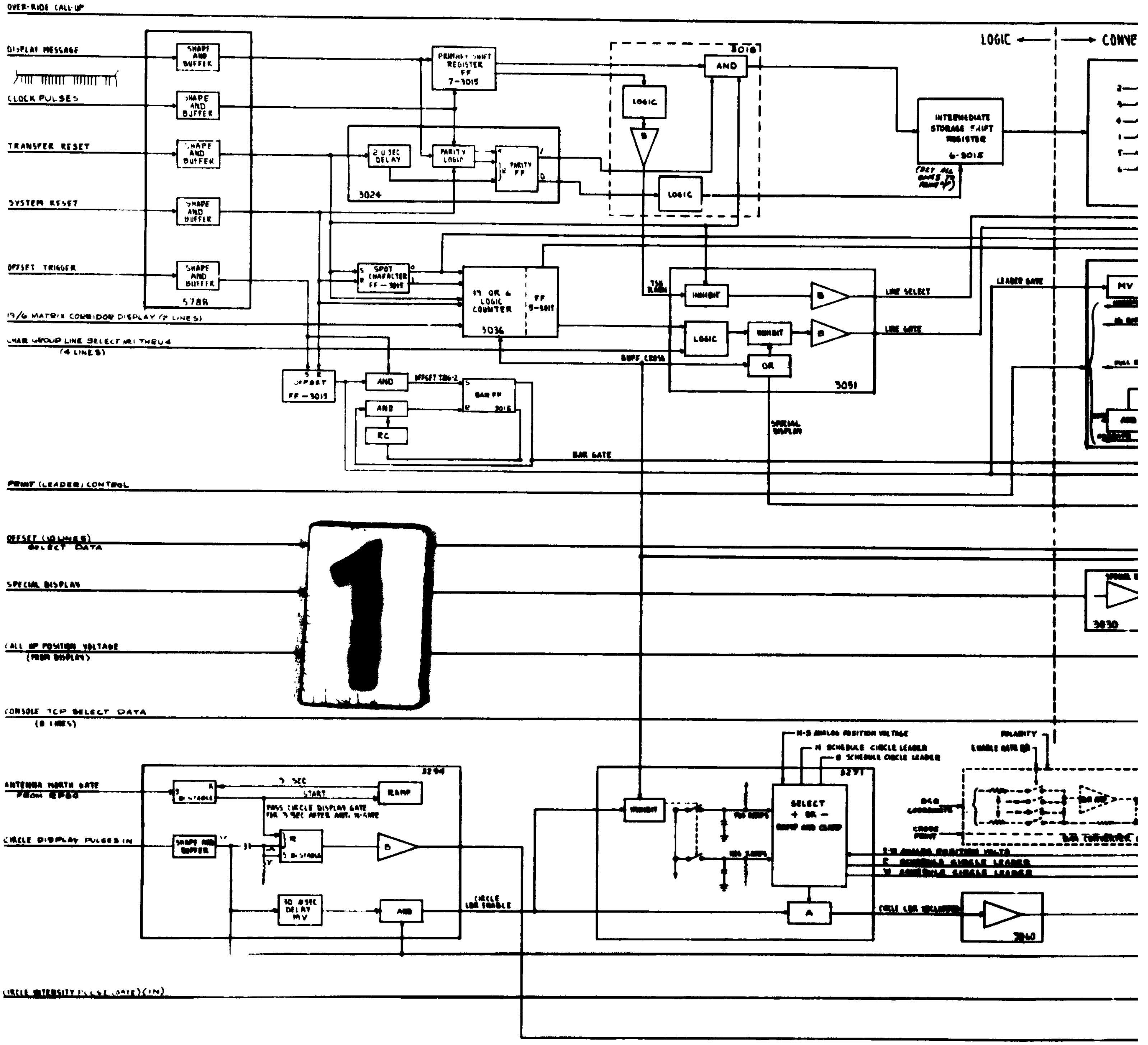
1.1.2.4 **RECOMMENDATIONS**

1.1.2.4.1 **SELECTION AND COMPENSATION VOLTAGES** - The present specifications for the Character Generator require analog selection and compensation voltages. Stringent noise requirements have been placed on these lines in order to prevent characters from smearing on the PPDD console. It is suggested that binary logic be used for these lines (three x lines and three y lines) and the analog to digital conversion be performed in the Display Module.

1.1.2.4.2 **INCREMENTAL DEFLECTION AND OFFSET VOLTAGES** - These analog lines require not only incremental step voltages but also leader sweep voltages. It is suggested that the signal voltage for these lines be increased by at least 3 to 1 and appropriate attenuation be placed at the PPDD unit processors. This will reduce noise requirements presently imposed on these lines.

1.1.2.4.3 **SPECIAL DISPLAY CALL-UP POSITION VOLTAGES** - These analog voltages are generated in the present equipment at the display modules and gated onto two time-shared lines in the PPDD unit processors. It is recommended that these voltages be summed with the voltages on the incremental and offset voltage lines in either the PPDD unit or PPDD unit processor chassis.

1.1.2.4.4 **VIDEO SIGNALS FROM CHARACTER GENERATOR** - The ID leader, circle leader and character intensity pulses are transmitted to the PPDD consoles via separate lines. It is recommended that these video signals be placed on the same lines and video gating be employed in the PPDD unit processor chassis for independent gain control processing.


OVER-RIDE CALL-UP
DISPLAY MESSAGE
CLOCK PULSES
TRANSFER RESET
SYSTEM RESET
OFFSET TRIGGER
SHAPE AND BUFFER
5788
PRIMARY SHIFT REGISTER FF 7-3015
2 u SEC DELAY
PARITY LOGIC
PARITY FF
3024
LOGIC
AND
3018
LOGIC
CONVE
INTERMEDIATE STORAGE SHIFT REGISTER
6-3015
SPOT CHARACTER FF-3015
19 OR 6 LOGIC COUNTER
3036
FF 5-3015
INHIBIT
LINE SELECT
LINE GATE
OR
3091
LEADER GATE
MV
19/6 MATRIX CORRIDOR DISPLAY (2 LINES)
CHAR GROUP LINE SELECT #1 THRU 4
(4 LINES)
OFFSET FF-3015
AND
BAR FF
RC
BAR GATE
SPECIAL DISPLAY
PRINT (LEADER) CONTROL
OFFSET (10 LINES)
SELECT DATA
SPECIAL DISPLAY
CALL UP POSITION VOLTAGE
(FROM DISPLAY)
1
3030
CONSOLE TCP SELECT DATA
(8 LINES)
ANTENNA NORTH GATE
CIRCLE DISPLAY PULSES IN
5 SEC
START
RAMP
PASS CIRCLE DISPLAY GATE FOR 5 SEC AFTER ANT. N-GATE
10 uSEC DELAY MV
CIRCLE LDR ENABLE
3291
N-S ANALOG POSITION VOLTAGE
N SCHEDULE CIRCLE LEADER
S SCHEDULE CIRCLE LEADER
SELECT + OR -
POLARITY
CROSS POINT
A
3060
CIRCLE INTENSITY PULSE (GATE)(IN)

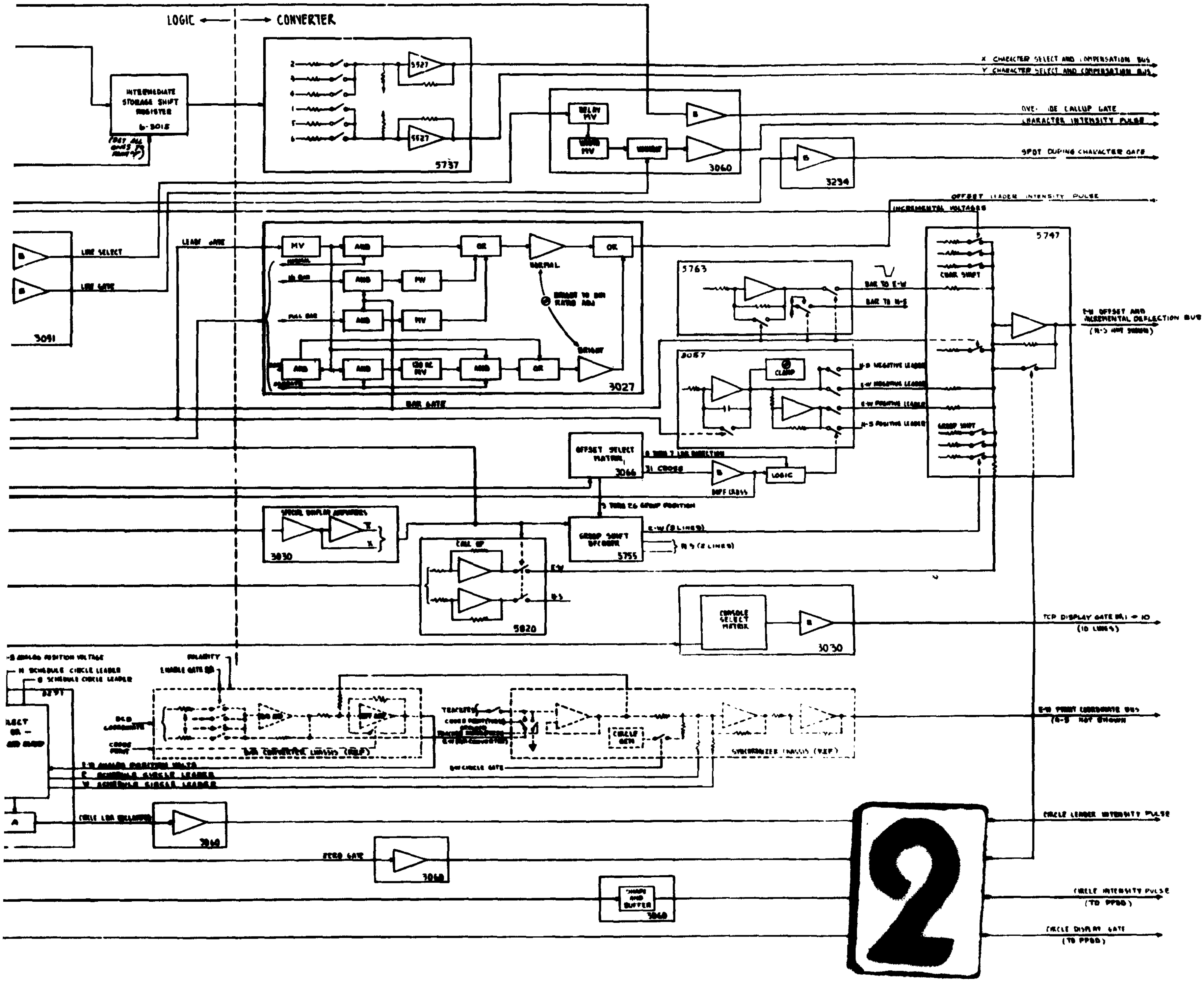


Figure 6. Character Generator, Block Diagram

1.1.3 TCP LAMP DRIVER

1.1.3.1 DESIGN OBJECTIVES

The TCP (Tracker Control Panel) Lamp Driver is used to control the operation of Tracker Selector lamps on the Tracker Control Panels and to temporarily store the local tracker numbers of Trackers as the Trackers are assigned to the individual Tracker Control Units.

The TCP Lamp Driver chassis is a functional part of the Video Track Programmer (VTP) and it was originally planned to house it in the VTP cabinet. Lack of space in the VTP cabinet required that the TCP Lamp Driver be located in the Condition-Generator Unit.

1.1.3.2 DESIGN ALTERNATIVES

The initial issue of GPL Specification 10000-523 required that each control panel have 50 lamps, one corresponding to each actual Tracker. An alternative was to time share local tracker numbers. The 50 lamps would have required much more storage, more logic and many more flip-flops, in addition to allowing more errors by the operator, due to the large number of pushbuttons. The present system, as changed by revision of Specification 10000-523, is more suitable.

Beyond this initial change in the design concept of this unit, there were no significant design alternatives. Design choices and changes have been concerned only with simplification of the required logic circuits.

1.1.3.3 FINAL DESIGN

1.1.3.3.1 GENERAL

The TCP Lamp Driver is digital in operation and is slaved to the VTP. Video Track Programmer clock pulses and gate signals are used to control its operations. The cards are standard VTP cards and consist of flip-flops, gate cards, and an inverter and a clock driver card.

1.1.3.3.2 LOGIC LEVELS AND TIMING - The chassis receives all normal logic level signals from the VTP via cable to the base of the rack. The clock signal comes to the Conditioner-Generator Unit base on a 75-ohm coaxial cable at low voltage levels. It is amplified in the TCP Lamp Driver to normal logic levels. This amplified clock pulse is also routed to the two Display Processor chassis, eliminating the need for clock amplifiers in the Approach Display

Processor chassis. The logic flow details for the TCP Lamp Driver are shown in TIC Drawing number 6034, Logic Summary VTP I, Tracker Switching Control Section, steps 7 thru 13. The detailed equations are given in TIC Drawing 6122, Logic Summary, Flip-Flop and Buffer Input, pages 90 to 98.

1.1.3.3.3 LAMP SIGNALS - The Tracking status of every Tracker under control of an operator is sent via the Synchronizer to the TCP Lamp Driver. By means of control signals from the VTP, this information is stored in the TCP Lamp Driver chassis in flip-flops which control the lighting of the Local Tracker Lamps assigned to these Trackers. Moreover, the additional brightness required by the Local Tracker Lamp of the Tracker which has been selected is controlled by the VTP through the TCP Lamp Driver. The Local Tracker Lamp signals are routed to all consoles. The correct console is selected at the Tracker Control Auxiliary by means of a console gate from the VTP.

1.1.3.3.4 TIE IN WITH VTP - The tracker switching track in the VTP storage drum is subdivided into ten sectors, each of which corresponds to a Tracker Control Panel. In each of these sectors, twenty characters are assigned local tracker number addresses, i.e., A1 through A0 and B1 through B0, (for alternate sectors, C1 through C0 and D1 through D0). In each of these addresses or slots are written the real number of the Tracker (1 through 50) if any, assigned to that local tracker number. These real tracker numbers refer to the location of the Tracker in the Video Tracker Unit. An address is also reserved on the sector for the number of any local Tracker that may have been selected by the operator on that Tracker Control Panel.

An operator selects a Tracker which has been assigned to him when he wishes to operate on the Tracker. Typical operations might be slewing, changing video, changing mode of tracking, changing offset, substituting the Tracker, or dumping the Tracker. More details on these operations will be found in the discussions of the Video Tracker Unit, the Tracker Control Group, and the Video Track Programmer. As the Video Track Programmer drum rotates, a read head on the tracker switching track sequentially reads into a flip-flop register the assigned tracker numbers. This register is tied to a matrix which has 50 output lines, one per Tracker. When the tracker number is written into the register, a signal is sent to the correct Tracker. This Tracker immediately sends to the TCP Lamp Driver via the Synchronizer, a status signal; steady if it is on target, or low-frequency pulsating if it is off target. The pulsation is accomplished by alternately sending the signal from the Tracker for a number of drum revolutions and then sending no signal from the Tracker for a number of revolutions.

1.1.3.3.5 TCP LAMP DRIVER LOGIC - The status signals of the Trackers assigned to the Tracker Control Panel are shifted serially into a register in the TCP Lamp Driver under control of a gate from the VTP. There are twenty flip-

flops in this register. In the logical equations, each of these flip-flops is referred to by the prefix TB followed by a number (1 to 20). Information is shifted in the order of increasing TB numbers. Since each shift corresponds to a local tracker number entry, upon completion of the shifting, the status of all twenty local tracker numbers is stored on the register. The status of local Tracker A1 is stored in TB20 and the status of local Tracker B0 is stored in TB1.

At the end of the sector, information in TB1 through TB20 is transferred into another register, TD1 through TD20, which controls switching of the ground return to the appropriate lamp. For example, if the flip-flop switch for lamp A0, TD20, is set, one end of all A0 lamps becomes grounded. This transfer frees flip-flops TB1 through TB20 for receipt of information from succeeding sectors.

The VTP sends out delayed console gate signals to each Tracker Control Auxiliary. Each gate is energized for a duration of about 1.5 milliseconds, almost one complete VTP drum sector. The line to a particular console is energized during the drum sector succeeding the one that contains the Tracker information for that console. Tracker Control Unit No. 2 has its Tracker information stored in sector 2 of the Tracker switching section of the Video Track Programmer drum. It will receive a delayed console gate signal during sector number 3.

This delayed console gate causes 28 volts to be applied to all local tracker lamps on the console, allowing any of them to be lit. Register TG1 through TG5 determines which lamp becomes lit.

About one millisecond after the delayed console gate is energized, the lamp register, TD1 thru TD20, is reset, disconnecting the lamp circuits from ground. This routine is cycled sequentially for all Tracker Control Panels using the same registers with only the delayed console gate selecting the correct panel. The repetition rate for energizing a lamp on a particular Tracker Control Panel is one drum revolution or 16.7 milliseconds. Because of the high repetition rate, the relatively high filament voltage applied to the lamps, and persistency of the human eye, the flicker of these lamps is not apparent. Only the low frequency blinking which specifies off-target status is noticeable.

During the sector that the assigned Tracker numbers are read off the drum and sent to the Trackers, the selected local tracker number, as stored on the drum, is read into a third flip-flop register, TG1 thru TG5. Seven microseconds after the TD register is reset, a gate from the VTP energizes a matrix which is tied to register TG1 thru TG5 (which stores the local tracker number of the selected Tracker). This matrix selects and sets the TD flip-flop which corresponds to the selected local Tracker. This causes completion of the lamp circuit for this local tracker lamp. This lamp is then turned off at the end of the sector. Since the selected local tracker lamp receives a voltage for almost twice as long as the other local tracker lamps, it appears brighter.

1.1.3.3.6 <u>TEST PROVISIONS</u> - Test points were located on the TCP Lamp Driver front panel to permit observations of the various driving gates and the status of some of the flip-flops for test and maintenance purposes. A test switch has been incorporated to permit checkout of the TCP Lamp Driver by means of a Video Track Programmer Simulator. Three lamps on the front panel indicate the status of the various TD flip-flops for testing and maintenance.

1.1.3.4 <u>RECOMMENDATIONS</u> - While the equipment was being fabricated, it became obvious that the following changes would facilitate checkout and maintenance:

a. Incorporation of built-in self-test routines

b. Addition of sufficient front-panel test points and/or indicators to show the status of all flip-flops

These changes were not incorporated because of the time required to change hardware and to rewire the chassis and because of insufficient space for test points on the front panel.

1. 1. 4 DIGITAL TO ANALOG CONVERTER

1. 1. 4. 1 DESIGN OBJECTIVES

The purpose of the Digital to Analog Converter is to perform the following operations in the Video Tracking System.

1. 1. 4. 1. 1 PRIMARY FUNCTION - The Digital to Analog Converter must accept digital data from the Video Track Programmer (VTP) Type I in the form of parallel 12-bit binary-coded-decimal signals and convert this information into analog positioning voltages. The output voltages are used for positioning of the missed-approach scehdule cross, the position circle (during Mode B operation), and the altitude waiting point to which a Tracker is to be slewed.

1. 1. 4. 1. 2 POSITION INPUTS - Position inputs from the VTP represent N-S and E-W coordinates within the range of -99. 9 and +99. 9 nautical miles for each coordinate. Altitude data inputs represent the range from 0 to 99, 000 feet.

1. 1. 4. 1. 3 LOGIC - The Digital to Analog Converter must convert signals which are present on its input lines only on instruction from the VTP. It must therefore contain the logic circuits necessary in order to recognize the instruction.

The Digital to Analog Converter must also contain logic circuits which will enable it to interpret and execute commands from the VTP which instruct it to operate in one of the following three modes:

a. Schedule cross
b. Position circle
c. Altitude

1. 1. 4. 1. 4 N-S AND E-W OUTPUTS - In the schedule circle and cross modes of operation, the Digital to Analog Converter must produce N-S and E-W analog positioning voltages at a scale of 0. 2 volt per nautical mile over the range from -19. 98 to +19. 98 volts in accordance with the input data.

1. 1. 4. 1. 5 ALTITUDE OUTPUT - The analog altitude output voltage must be at a scale of 0. 2 volt per 1000 feet over the range from 0 to +19. 8 volts, nominal.

1.1.4.1.6 ACCURACY - Converted data must have an error spread not greater than ±0.02 volt.

1.1.4.1.7 SETTLING TIME - The Digital to Analog Converter output voltages must settle to the proper output level, in accordance with the input data, within the time required for the printing of Mode B circles, leaders and schedule crosses.

1.1.4.1.8 NOISE - Noise on any analog output line must be small enough in amplitude so that there will be no disruptions or adverse effects on the operation of the Video Trackers and the PPD Displays.

1.1.4.2 DESIGN ALTERNATIVES

1.1.4.2.1 VOLTAGE SWITCHING - The first digital to analog technique considered was to utilize transistors as voltage switches. In this technique, the digital information would turn off a transistor, driving the collector voltage to a certain clamped voltage level. This level would be summed through summing resistors into an operational amplifier and the sum of the various weighted bits would give the final analog output.

1.1.4.2.3 HIGH VOLTAGE POWER SUPPLY - Another technique considered was to incorporate two precision high-voltage power supplies into the Conditioner-Generator Unit to reduce the effect of switching-diode voltage drop variations.

1.1.4.2.2 CURRENT SWITCHING - This method employs diode switches which permit current flow through weighted resistors. The resistors are weighted in accordance with the value of each binary bit. The method is described in detail in paragraph 1.1.4.3.2.

1.1.4.3 FINAL DESIGN (See figure 8.)

1.1.4.3.1 CHOICE OF FINAL DESIGN - The alternative of using voltage switching was rejected because it presented difficulties in temperature compensation and alignment, and because of expense.

The use of high-voltage power supplies was rejected because of expense, the length of time required for design, and lack of space in the Conditioner Generator.

Current switching was selected as the digital to analog conversion technique because of its economy and simplicity.

1.1.4.3.2 <u>OPERATION</u> - The input signals to the Digital to Analog Converter are:

a. Parallel binary-coded-decimal digital signals from the Video Track Programmer at the logic levels -12 (+2, -0) volts = ONE and 0, (+0-3) volts = ZERO.

b. Polarity control signal

c. Gate control signal

These input signals are fed to the Digital to Analog Converter Switching Assembly circuit card where the true signals are used to generate the positive analog output voltage and the complementary signals are used to generate negative output voltages. Figure 7 shows the method of switching weighted currents in order to convert the digital signal to a corresponding analog voltage.

When the digital number is written in binary-coded decimal form, it can be seen that it is possible to obtain values which are equivalent to one times the least significant digit, two times the next least significant digit, four times the third least significant digit and eight times the most significant digit for each decade. These values represent numbers which correspond with the weighting of the digits. In the case of the tens digit, each value is multiplied by ten. In the case of the tenths digit, each value is multiplied by 0.1. In Figure 7, D_1 through D_{12} represent the twelve binary-coded decimal digits and each digit can be either a zero or a one. The weighting of each digit is shown directly above the digit in the diagram. By multiplying D_1 times its weighting value, D_2 times its weighting value, and so on, the decimal equivalent of the bcd number is produced.

To utilize weighted coding, resistor networks are selected which will pass currents in proportion to the weighting of each digit. These currents are turned on and off by the corresponding bits of the bcd signal. Thus, in multiplying D_{11} by 40, the current through the D_{11} resistive network is turned on by the third bit of the third decade, and a current, which is the analog of 40 flows through the D_{11} network.

When the control signal on control C_1 is negative, the current from voltage supply Vs flows through diode CR_1 and into the control signal source. Diode CR_2 is cut off so that there is no input to the operational amplifier. If the control voltage at input C_1 is at zero volts, the cathode of diode CR_1 will tend to rise above ground level, CR_1 will cut off, CR_2 will conduct, and current from Vs will flow into the operational amplifier. By means of separate logic controls, either of the two weighting systems can be selected.

Where several of these switches are connected in parallel, the operational amplifier provides an output voltage which is proportional to the input current. The value of the output voltage is determined as follows:

$$V_o = \frac{V_s \times R_2}{R_1}$$

If an output of the opposite polarity is desired, then the complementary control input, C_2, is used. The complementary control input utilizes the complement of the control signal, so that operation is the same as operation at the C_1 input, except for the reversal of sign.

The D/A Converter Switching Assembly circuit card contains circuits which turn on the appropriate control input and also contains the line gate which can eliminate any output from the Digital to Analog Converter. The gated bcd signals are then fed to the input assembly No. 1 and input assembly No. 2 circuit cards. These cards contain the weighting resistors and the actual current mode switches. Outputs from the switches are summed on a summing bus and then fed to the first summing amplifier as shown in Figure 8, the Digital to Analog Converter Block Diagram. The output of the summing amplifier is the actual analog voltage output which corresponds to the digital input. The output of the first summing amplifier is fed to a second summing amplifier which has a gain of five. The scaling of the first amplifier is such that a binary input of 20 results in a 20-volt output from the first summing amplifier.

The output from the second amplifier (differencing amplifier) is five times that of the first amplifier, but the total swing is limited to 10 volts by Zener diodes in parallel with the feedback resistor. The print coordinate signal is a second input to the differencing amplifier. Therefore, the output of the differencing amplifier is the difference between the Mode B circle coordinate and the Tracker coordinate. This output is fed to the Character Generator where it is utilized to control the length of the Mode B circle leader.

There is a six-diode switch between the input and output of the differencing amplifier. This switch disables the differencing amplifier during the time that a Cross Print signal is present at the cross-print input to the Digital to Analog Converter, so that the output is zero when crosses are being printed.

1.1.4.3.3 MAJOR PROBLEMS AND SOLUTIONS - The major problem in designing the Digital to Analog Converter was in meeting the required accuracies. The prime factors affecting the accuracy are the value of R_1 (Figure 7), its tolerance, the tolerance of V_s, and the predictability of the major digit, D_{12}. All of these effects are most serious in the cases of the major digits. Variation of D_{12} is known from the physics of semiconductors, so that manufacturers can supply the parameters of D_{12} for any particular current and temperature. Since the parameters are predictable, R_1 can be given a temperature coefficient to

compensate for temperature variations. This was done for the six major digits.

1.1.4.3.4 ENGINEERING CHANGES - Final system interface problems concerning the Digital to Analog Converter were not resolved until late in the program and as a result, engineering changes were necessary after the equipment had been fabricated. One of these was the addition of a six-diode switch which is used to turn off the differencing amplifier during cross print.

1.1.4.4 RECOMMENDATIONS

Settling time can be improved by incorporation of improved operation amplifiers. The present operational amplifiers utilize the design originally intended for use in the Character Generator and the Analog Computer. They are somewhat marginal and it was necessary to limit the speed of operation in order to meet the required output accuracies. The present settling time of 100 microseconds can be reduced to 10 or 20 microseconds for a ±0.1 percent accuracy by incorporation of a newly designed amplifier. It may also be necessary to change some diodes to improve the settling time.

Fabrication of the Digital to Analog Converter had been completed before the new operational amplifier had been designed. Since operation of the Digital to Analog Converter with associated input and output equipment was satisfactory, it was decided not to expend time and money in incorporating the new amplifiers.

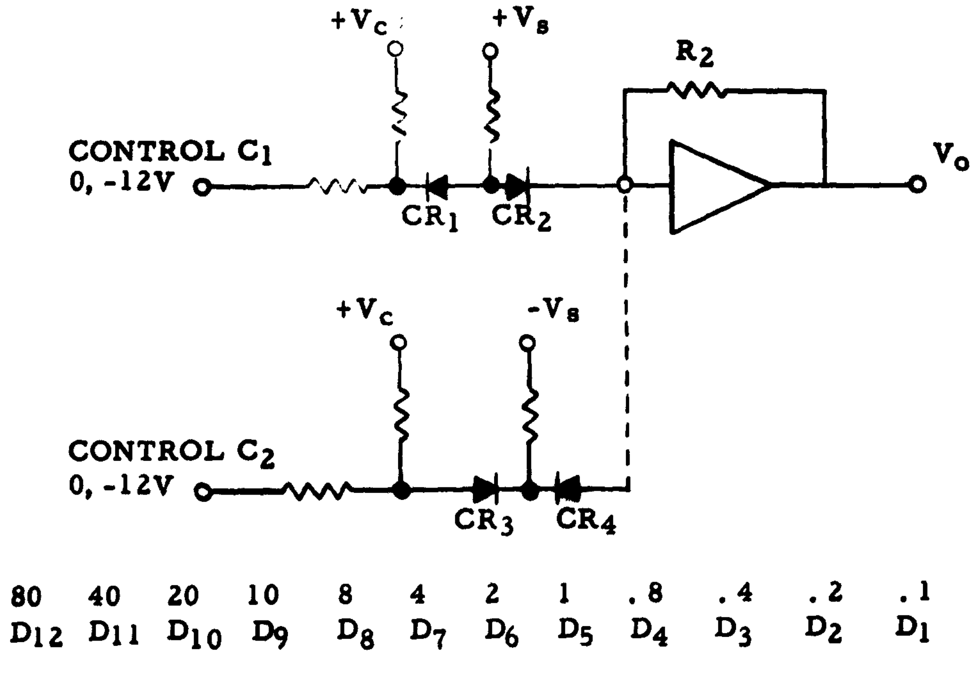
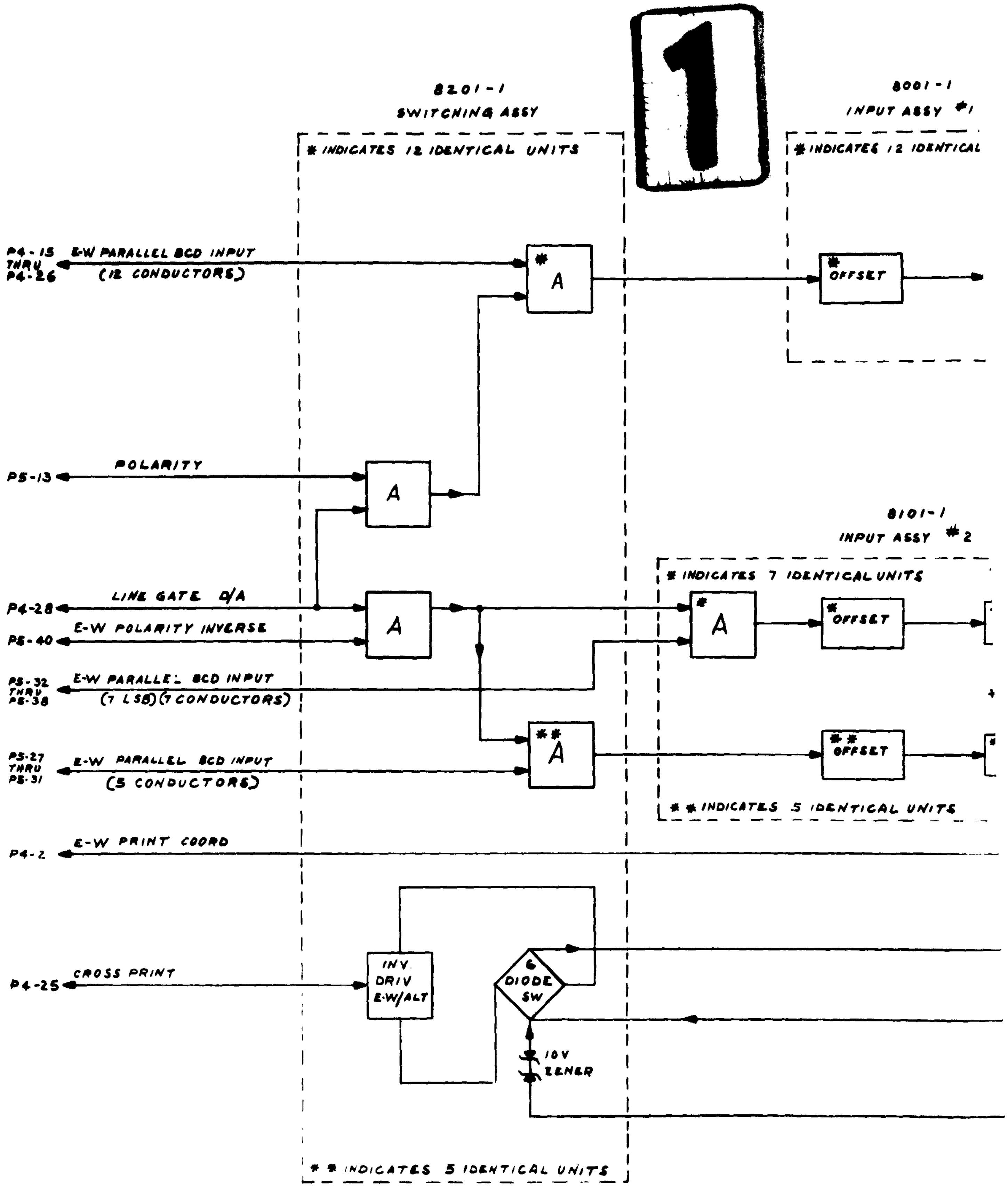


Figure 7. Current Switching In Digital to Analog Converter


1
8201-1
SWITCHING ASSY
* INDICATES 12 IDENTICAL UNITS
8001-1
INPUT ASSY #1
* INDICATES 12 IDENTICAL
P4-15 THRU P4-26
E-W PARALLEL BCD INPUT
(12 CONDUCTORS)
A
OFFSET
P5-13
POLARITY
8101-1
INPUT ASSY #2
* INDICATES 7 IDENTICAL UNITS
P4-28
LINE GATE D/A
P5-40
E-W POLARITY INVERSE
P5-32 THRU P5-38
E-W PARALLEL BCD INPUT
(7 LSB)(7 CONDUCTORS)
P5-27 THRU P5-31
E-W PARALLEL BCD INPUT
(5 CONDUCTORS)
** INDICATES 5 IDENTICAL UNITS
P4-2
E-W PRINT COORD
P4-25
CROSS PRINT
INV. DRIV E-W/ALT
6 DIODE SW
10V ZENER
** INDICATES 5 IDENTICAL UNITS

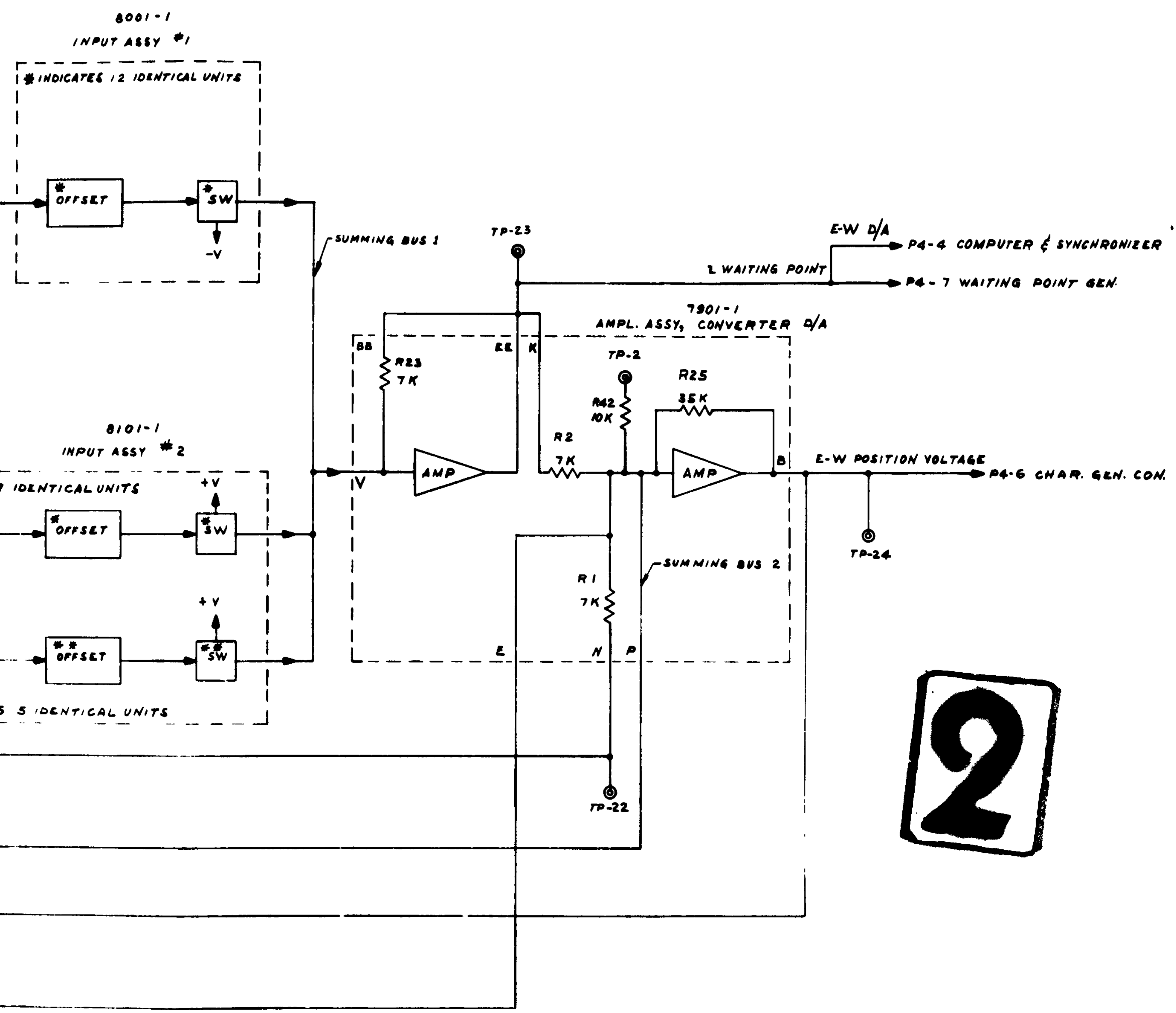


Figure 8. Digital To Analog Converter, Block Diagram

1. 1. 5 APPROACH DISPLAY PROCESSOR

1. 1. 5. 1 DESIGN OBJECTIVES

1. 1. 5. 1. 1 DRIVING OF DISPLAYS - The Approach Display Processor must drive the alpha-numeric and numeric indicators of the two Approach Display assemblies in parallel (refer to paragraph 1. 5. 1).

1. 1. 5. 1. 2 CONVERSION OF MESSAGES - The Approach Display Processors must convert messages which are received from the Video Track Programmer serially in binary-coded decimal form into appropriate codes for controlling the alpha-numeric display. The alphabetic indicators are controlled by means of a 4 out of 8 code on eight input lines and read in lines. The numeric indicators are controlled by a 3 out of 6 code on six input lines.

1. 1. 5. 1. 3 UPDATING OF DISPLAYS - The Approach Display Processor must supply information to the Local Approach Display and PAR Approach Display assemblies in order to update the ID (identity) and time-to-fly displays (refer to paragraph 1. 5. 1. 1). It must also control downshifting of ID and time-to-fly readouts of the Approach Display assemblies every time that the landing sequence is advanced one landing slot by the landing of an aircraft.

1. 1. 5. 2 DESIGN ALTERNATIVES

1. 1. 5. 2. 1 SEPARATE ID AND TIME UPDATES - In the early stages of development, it was intended to start the downshift operation upon receipt of data from the Video Track Programmer (VTP) specifying an ID update. Completion of the downshift from Row 4 to Row 5 was to initiate the downshift from Row 3 to Row 4. This process was to continue until all rows had been laddered down, with the Display Processor controlling the sequence of downshift.

At the same time, time-to-fly updates were to be received by the Approach Display Processor and fed to the Approach Display assemblies where the time-to-fly readouts would be updated prior to completion of the laddering-down process. Upon completion of the downshift into Row 2, a message was to be sent to the VTP requesting ID rather than time-to-fly.

The ID for Row 1 (top row) would then be sent by the VTP, processed by the display processor, and entered into Row 1 of the approach display assembly. When this entry had been completed, normal time-to-fly update routines were to be resumed. The primary advantage of this approach would have been the up-

dating of ID information at the maximum rate of change of the display indicators. The minimum time for the complete routine would therefore be small, even though the maximum would be approximately 15 seconds. The major disadvantage would have been the incorrect correlation between the ID and time-to-fly indications which would exist during the laddering-down process, until all rows had been downshifted.

1.1.5.2.2 SIMULTANEOUS UPDATES - An alternative was to downshift both ID and time-to-fly simultaneously. This would eliminate the error in row correspondence but would make it impossible to update a time-to-fly until the downshift operation and the ID update had been completed. This method would also have required more hardware and would have increased the cost of the time-to-fly display circuits.

1.1.5.2.3 RESEQUENCING OF TIME TO FLY - A third approach was to have the Display Processor resequence each time to fly received on an update, so that each time-to-fly display would correspond with the proper ID during the laddering process. The maximum time for error in correspondence, in this case, would be the time between successive time-to-fly updates. This method would permit identity downshifting at the maximum operating rate of the Approach Display assembly.

1.1.5.3 FINAL DESIGN

1.1.5.3.1 PHYSICAL CONFIGURATION - The Approach Display Processor group consists of two chassis assemblies, the Conversion Display Processor and the Control Display Processor (see figure 1). Some control circuits have been placed in the Conversion Display Processor in order to physically limit the Approach Display Processor to two chassis.

Standard Conditioner-Generator Unit chassis have been utilized in the design of the two assemblies. Both chassis contain etched circuit cards of the type used throughout the VTP Unit. Flip-flop, power driver, gates and an inverter and clock driver cards are employed.

1.1.5.3.2 OPERATION - There are three basic routines in the operation of the Approach Display Processors as follows:

1. Start Up
2. Time-to-Fly Update
3. ID (Identity) Update

1. 1. 5. 3. 2. 1 START UP - The local controller initiates the start-up operation by pressing the START button either when the equipment is first turned on or when the controller suspects that a readout may be incorrect. When the START button is pressed, the Local Approach Display assembly feeds a start-up signal to the Video Track Programmer (VTP). The VTP then generates a start-up approach display message which is sent to the Digital Computer. The Digital Computer then sends a series of five messages to the VTP. These messages contain the identities of the five aircraft (or blanks) in the five slots closest to touchdown (or takeoff). The first message contains information for Row 5 and succeeding messages contain information according to the sequence of decreasing row numbers. The time spacing between numbers is approximately six seconds, as controlled by the Digital Computer.

1. 1. 5. 3. 2. 1. 1 IDENTITY WRITE-IN - Identities are sent from the VTP to the Approach Display Processor in the same sequence at approximately six-second intervals. The six-second timing of messages from the VTP is not a result of the timing of messages from the Digital Computer, but results from a multiple of print cycles which occur within the VTP. A print cycle occurs within the VTP approximately every three seconds, so that if data is made available more frequently by the Digital Computer, it can be entered into the Approach Display Processor at three-second intervals. Therefore, the time required to enter all identities during the start-up routine is approximately 30 seconds.

The message from the VTP is shifted serially into a 56-bit storage flip-flop register in the Approach Display Processor under control of a gating signal from the VTP. When a character has been shifted completely into the register, a command from the VTP causes the Approach Display Processor to convert the character into the indicator code. When the entire message has been completed, the VTP sends an end-of-shift gate to notify the Approach Display Processor that the shifting operation has been completed.

A three flip-flop row counter and matrix in the Approach Display Processor determines the row into which an identity is to be entered. The row counter is stepped by the end-of-shift gates. Outputs from the 56-bit register are fed to the Approach Display assembly on a time-shared basis, under control of the row counter matrix. In this manner, information is written into the Approach Display assemblies one row at a time. The Local Approach Display and PAR Approach Display respond simultaneously and in identical manner.

1. 1. 5. 3. 2. 2 TIME-TO-FLY UPDATE - Time-to-fly information is sent from the Digital Computer to the Approach Display Processor at regular six-second intervals. The information is stored by the VTP and at three-second intervals, just prior to each print cycle, time-to-fly information for all five rows is sent from the VTP to the Approach Display Processor. This routine is inhibited when identity information is sent to the Approach Display Processor during an ID

Update (Paragraph 1. 1. 5. 3. 2. 1. 1).

Time-to-fly information is conveyed to the Approach Display Processor in the same manner as identity information. A 65-bit flip-flop register which consists of the 56 flip-flops used for identity storage plus nine additional flip-flops is used to store the time-to-fly information. On each time-to-fly update, all five rows of the Approach Display assemblies are updated simultaneously.

Time-to-fly information is shifted into the 65-bit time-to-fly storage register so that, on completion of the shifting process, data is arranged according to the sequence of row numbers. Therefore, it is normally not necessary to rearrange the time-to-fly data within the Approach Display Processor before sending it to the Approach Display assemblies.

Upon receipt of the end-of-shift gate from the VTP, the Approach Display Processor sends a numeric read-in gate to the Approach Display assemblies for the time interval required by the Approach Display indicators in assuming the positions which correspond with the data stored in the time-to-fly register.

Another gate from the VTP causes the numeric read-in gate to go false at the end of the time-to-fly update and also initiates a 56-microsecond numeric parity gate which is sent to the Approach Display assemblies. During this period, the reading of each time-to-fly indicator in the Approach Display assemblies is compared with the respective time-to-fly data in the shift register of the Approach Display Processor. If there is a discrepancy, the TIME ERROR lamp becomes lit on the Approach Display assembly at which the error is present.

1. 1. 5. 3. 2. 3 <u>IDENTITY UPDATE</u> - There are two types of identity update, Touchdown (TD) and Missed Approach (MA).

1. 1. 5. 3. 2. 3. 1 <u>TOUCHDOWN ID UPDATE</u> - This routine is initiated by the Local Controller by means of the TD (touchdown) pushbutton on the Local Approach Display (see figure 25). When pressed, the TD pushbutton sends a signal to the VTP and the Approach Display Processor. In the Approach Display Processor, a flip-flop is set to record the fact that a touchdown has occurred. This information is used later to distinguish between a normal ID update and the TD update.

On receipt of the signal from the Local Approach Display, the VTP sends a touchdown message to the Digital Computer. The Digital Computer then responds with an ID update message which is identical to the message used to initiate the Missed Approach update routine. From this point on, the update routine is identical to the routine described in Paragraph 1. 1. 5. 3. 2. 2, except that the first downshift on the Local Approach Display is from Row 5 to Row 6.

When the aircraft is next to land, the Local Controller can initiate the Missed Approach (MA) identity update by pressing the MA pushbutton on the Local Approach Display assembly. When the pushbutton is pressed, the Video Track Programmer sends a Missed Approach message to the Digital Computer. The Digital Computer in response, sends an identity update message to the VTP. This message contains the identity of the next aircraft to land or a blank (if the next slot is unassigned). The message causes flip-flop KM7 in the VTP to become set. Successive time-to-fly messages from the Digital Computer to the VTP contain the time to fly for the new identity plus the time to fly for each of the four other identities. All five times to fly are sent to the VTP in a sequence which corresponds with the row positions of the five identities after completion of the downshift.

1. 1. 5. 3. 2. 3. 1. 1 INITIATION OF UPDATE ROUTINE - It is important that neither the controller nor the Digital Computer initiate any of the above types of ID update routines until the previous update has been complete.

1. 1. 5. 3. 2. 3. 2 MISSED APPROACH UPDATE - The local controller can utilize the MA pushbutton only for missed approach routines which involve the aircraft which is in the next-to-land slot. For any other landing slot, the missed approach routine must be initiated by sending a message to the Digital Computer by a medium such as a data entry keyboard. The Digital computer must store this information and send the appropriate update messages when the missed approach aircraft is in the next-to-land slot.

1. 1. 5. 3. 3 MAJOR PROBLEMS AND SOLUTION

1. 1. 5. 3. 3. 1 READ IN COMPLETE SIGNAL - Initially, a read-in complete signal from Approach Display assemblies was used to enable the information inputs in the Approach Display Processor in preparation for a new information input form the Video Track Programmer. It was discovered that a malfunctioning display indicator in one of the Approach Display assemblies would delay the read-in complete signal so that the following information input was processed incorrectly by the Approach Display Processor. This caused incorrect readouts in both Approach displays. To correct this situation, the present system utilizes a signal from the VTP to reset the Approach Display Processor read-in lines. The signal now occurs slightly prior to the shifting in of new data. This method assumes that the Approach Display assembly indicators are correctly set by the time that the read-in complete signal occurs. In this manner, only defective indicators can display incorrect data.

1. 1. 5. 3. 4 ENGINEERING CHANGES - During the initial phase of checkout, it was found necessary to add circuits for the following purposes:

a. To preload power drivers which wo into large wiring capacitances in order to speed up signals.

b. To reset flip-flops to the desired initial states when Conditioner-Generator Unit power is initially turned on, so that the Approach Display Processor is prepared to receive messages from the Video Track Programmer. Resetting the flip-flops also disables read-in gates which would cause the approach display indicators to hunt when non-permissible codes are set up in the data register. Continuous rotation of the indicators, under this condition, could result in failure of the indicators.

c. To improve facilities for static checkout of the Approach Display Processor when a Video Track Programmer Simulator or similar test set is used.

These additional circuit components were installed on terminal boards within the two chassis because sufficient space was not available on existing circuit cards.

In addition to the above changes, recessed switches were added to the front panels of both Approach Display Processor chassis for testing of the data register without using the Video Track Programmer. This is done by applying simulated clock pulses.

A pushbutton switch was also added for testing of the row counter register.

Front-panel test points were added for maintenance and testing and eight front-panel indicator lamps were added to the Conversion Display Processor to indicate the status of flip-flops which perform the code conversion.

1. 1. 5. 4 RECOMMENDATIONS

The following changes are recommended:

a. Addition of test points to both chassis to facilitate checkout of flip-flops and registers.

b. Incorporation of self-test routines.

1.1.6 CONDITIONER-GENERATOR UNIT POWER SUPPLIES

1.1.6.1 DESIGN OBJECTIVES

1.1.6.1.1 LOAD REQUIREMENTS - The original load requirements for the Conditioner-Generator Unit power supplies were as follows:

CHARACTER GENERATOR REQUIREMENTS

Volts DC	*Regulation	Ripple	Load (ma)
-45	0.5%	0.1%	200
-24	0.5	0.1	10
-24	3.0	0.1	250
-18	3.0	0.1	250
-12	3.0	0.1	1000
+12	3.0	0.1	500
+18	3.0	0.1	250
+45	0.5	0.1	200

* No load to full load and ±10% variation in input voltage

VIDEO CONDITIONER REQUIREMENTS

-45	1.0	0.1	500
-24	1.0	0.1	100
-12	3.0	0.1	100
+12	3.0	0.1	250
+24	1.0	0.1	100
+45	1.0	0.1	500

1.1.6.1.2 OVERLOAD PROTECTION - The power supplies were to be overload protected.

1.1.6.1.3 DUPLICATION OF SUPPLIES - The use of separate supplies for the Character Generator and for the Video Conditioner unit was mandatory to avoid common coupling problems which increase design complexity.

1.1.6.1.4 PHYSICAL REQUIREMENTS - Power supplies were to be mounted within standard drawers designed for the system. These drawers are of two sizes, the smaller size dictating maximum power supply package height. Other system considerations dictated the use of the minimum number of connector pins per connector to enable easy removal of units from the cabinet.

1.1.6.1.5 <u>STANDARDIZATION</u> - System considerations dictated the standardization of power supply units to permit interchangeability and mass production utility.

1.1.6.1.6 <u>REGULATION</u> - All requirements for load current and regulation were examined in relation to requirements for other units in the system and designs compatible to all finalized.

1.1.6.1.7 <u>PRIMARY POWER</u> - All supplies were to operate from 115 volts, ±10 percent, 60 cps ±5 percent primary power.

1.1.6.1.8 <u>ENVIRONMENT</u> - The supplies were to be designed to withstand the following environmental conditions:

a. Temperature: 10 to 60°C

b. Humidity: 95% at 50°F; 50% at 100°F

c. Coastal service environment

d. Altitude to 15,000 feet

e. Storage and Transport Temperature: -65 to ±130°F at 95 percent RH (no condensation)

1.1.6.1.9 <u>STABILITY</u> - Outputs were to be adjustable over a ±7 percent voltage range and were to operate for at least 200 hours without adjustment.

1.1.6.2 <u>DESIGN ALTERNATIVES</u>

The following design alternatives were considered:

a. Magnetic, transistor and vacuum tube regulated supplies were considered as design possibilities.

b. Both silicon and germanium semiconductors were considered.

c. Transient response time, both line and load, were considered in final determination of suitability.

d. The character of the load circuit was considered to determine suitability of the design approach.

e. Size and efficiency were considered as limiting factors in the selection of the type of supply.

1.1.6.3 FINAL DESIGN

1.1.6.3.1 **SELECTION OF FINAL DESIGN** - Transistor-regulated power supplies utilizing germanium regulating elements were selected in preference to magnetic and vacuum tube types, for the reasons listed below:

a. Best transient recovery consistent with small size (magnetic units slow in recovery time).

b. No filament power required.

c. More efficient at the low voltages used.

d. Long term service and reliability.

e. Readily short-circuit and overload protected.

f. No warm-up time required.

1.1.6.3.2 **PURCHASED UNITS** - The final design utilized purchased units of modular sizes compatible with system packaging. Output voltages were changed during the course of Conditioner-Generator Unit circuit development, as well as load currents. However, minimal changes were made by utilizing units of common design in multiple. Requirements for ±18 volts dc were eliminated in all system units, the load being placed on 24-volt d-c supplies. Specifications were written, bids were advertised and contracts let to suppliers for the following units:

	Power Supply	Specification
1.	12 vdc at 2 amp, ±3.0% Reg.	TES 1083
2.	24 vdc at 0.5 amp, ±0.5% Reg.	TES 1086
3.	24 vdc at 7 amp, ±3.0% Reg.	TES 1087
4.	30 vdc at 2 amp, ±3.0% Reg.	TES 1091
5.	45 vdc at 1 amp, ±0.05% Reg.	TES 1089

1.1.6.3.3 **PACKAGING** - Power supply units were packaged to provide interchangeable assemblies as follows:

TIC Assembly	Module	Spec.	No. Required
3926			4
	24 vdc ±0.2%	TES 1086	4
	45 vdc ±0.05%	TES 1089	4
3929			2
	12 vdc ±3.0%		2
	30 vdc ±3.0%	TES 1091	2

3932			2
	24 vdc ±3.0%	TES 1087	2
3935			1
	24 vdc ±0.2%	TES 1086	1
3938			
	12 vdc ±3.0%	TES 1083	1

Figure 9 is an illustration of the TIC 3926 Power Supply assembly which is typical.

1.1.6.3.4 CURRENT RESERVE - Total power provided ensures adequate current reserve for the addition of the TCP Lamp Driver Assembly, the Digital to Analog converter and the Approach Display Processor where required.

1.1.6.3.5 CIRCUITS - Each power supply module consists of a transformer, rectifier, filter (usually capacitor input), series transistor regulator and a transistor feedback amplifier. Each supply incorporates overload current control transistors which cut off the series regulator in event of overload. All supplies utilize germanium transistors. Voltage control has been provided by means of an external potentiometer (mounted on the panel assembly) which permits adjustment of approximately ±7 percent. Test jacks on the front panel of the assembly drawer permit convenient measurement of output voltage. Fuses in the a-c input circuits of all supplies provide protection in the event of component failure.

During circuit development for the system, it became mandatory to provide protection for voltage-sensitive transistor circuits. Consequently, overvoltage protection circuits were designed and installed to limit the voltage at the power-supply output terminals. It was impractical to determine exact maximum tolerable voltage level for each circuit connected to any given supply potential. Consequently, all designs provide that the overvoltage control potential level be within the adjustable range of output voltage, that is, within seven percent above the nominal output voltage. The overvoltage circuit causes excess load current to flow when the control potential is reached. Output voltage from the supply is then reduced by over-current protection devices within the supply and the internal impedance of the supply. Reverse connected diodes are also provided across the terminals of all supplies. These diodes prevent damage to power supply components in the event that an external circuit failure results in application of reverse potential to the supply output terminals.

1.1.6.4 RECOMMENDATIONS

Changes recommended during the program included replacement of rectifier diodes types 1N2069 and 1N2070 by units having higher reliability factors. Also desirable is the incorporation of overvoltage control devices within the original power supply

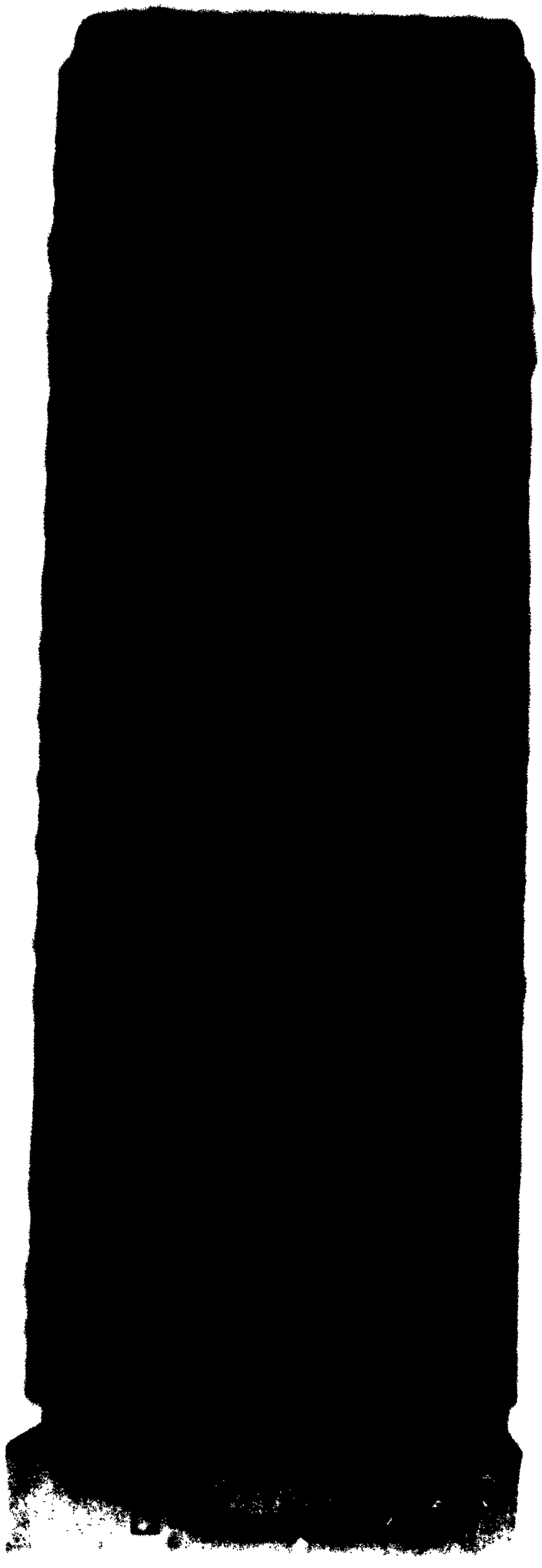


Figure 9. Power Supply Assembly, TIC Part No. 3926

design. Improved mounting lugs were found necessary in all supplies and were changed as time and costs involved permitted.

Cost considerations prevented the incorporation of the above design improvements except as noted.

1. 1. 7 CONDITIONER-GENERATOR UNIT CABINET

1. 1. 7. 1 DESIGN OBJECTIVES

This cabinet was designed to contain the chassis previously described, plus any additional circuit hardware that might be required for proper operation. The original intent was that this be a developmental model. Subsequent changes to the contract resulted in delivery of equipment superior in quality to a developmental model. The basic design parameters specified in GPL Specifications No. 10000-523 and 10000-590 were used as design guides. Subsequent changes to these specifications were incorporated where possible in the mechanical design.

1. 1. 7. 1. 1 SYSTEM UNIFORMITY - The prime contractor specified uniformity of the entire system produced by the various contractors and this was an important objective. Therefore, at an early stage, consultations were held with the prime contractor to assure the greatest uniformity possible, considering the variation of the equipment requirements.

1. 1. 7. 1. 2 SIZE - It was necessary to establish the minimum size which would accommodate circuit designs which had already been established and also provide space for additional circuit hardware, if necessary.

1. 1. 7. 1. 3 WEIGHT - The floor loading was the limiting factor in regard to the weight of the cabinet. Ease of handling was the limiting feature in regard to the weight of the individual chassis.

1. 1. 7. 1 MAINTAINABILITY AND RELIABILITY - Maintainability and reliability were important design considerations.

1. 1. 7. 1. 5 CABLING - Provisions for cabling were considered in the basic design.

1. 1. 7. 1. 6 ENVIRONMENT - GPL Specification 10000-523 dictated the environmental design considerations.

1.1.7.2 DESIGN ALTERNATIVES

1.1.7.2.1 COMPONENT MOUNTING - The following methods of component mounting were considered:

a. Plug-in printed-circuit cards

b. Plug-in wired cards

c. Fixed-wired component boards

d. Encapsulated assemblies

1.1.7.2.2 CHASSIS DESIGN - The following chassis designs were considered:

a. Front-panel mounted chassis with connectors or terminal blocks at the rear,

b. Slide-in chassis with plug-in connectors at the rear

c. Slide-in chassis with pendant cables

d. Chassis assembled as bins into a bay and hinged from the side. In this configuration, inter-bin wiring would be integral to the bay and only a single cable would come from the bay.

e. A slide-out bay consisting of chassis assembled as bins. The wiring of this configuration would be the same as d. above.

1.1.7.2.3 RACK DESIGN - The following rack designs were considered:

a. A specially designed rack to hold any of the chassis combinations mentioned above

b. Standard rack with internal struction modified to meet any of the conditions mentioned above.

c. Completely standardized prefabricated rack

In addition to the basic designs listed, the various possibilities of mounting power supplies were considered as follows:

a. One large fixed power panel with individually removable power supplies

b. Combinations of power supplies mounted in slide-out chassis with plug-in connectors at the ends of the chassis

c. Same as b. above with pendant cable connection at the rear

d. Power supplies mounted on a slide-out or hinged-out frame

1.1.7.2.4 COOLING - The following methods of cooling were considered:

a. A fan located at the top or the bottom

b. An air intake at the top, rear or bottom

c. An air outlet at the top, rear or bottom

d. Upward moving air, downward moving air, or recirculating air

1.1.7.3 FINAL DESIGN

1.1.7.3.1 COMPONENT MOUNTING - Since most circuits in this system are transistorized, components for the most part are small. For that reason, the prime contractor and TIC decided upon a standard plug-in wired or printed-circuit card. The dimensions established for the card were 8-1/2 inches high, 6-1/4 inches wide and 1/16 inch thick. A standard hole pattern for component mounting was established in order to simplify layout and wiring. The first cards were wired to provide for modifications of circuit design. After the design was completed, printed-circuit cards were produced. These printed-circuit cards, however, still retained the capability of modification through wiring. Card keying was provided to prevent rotation of a card by 180 degrees or installation of a card in the incorrect slot.

In certain instances where encapsulation proved to be an advantage, encapsulated modules were designed. Unusual circuits such as filters and high power devices were mounted on standard component boards and wired in place.

1.1.7.3.2 CHASSIS DESIGN - As noted in paragraph 1.2.3.3.2, the design of individual plug-in chassis was dictated by the need for 50 individual Tracker assemblies. This design was then utilized for all chassis except for some power supplies. Two basic power-supply chassis sizes were established.

A 22-1/8 inch long by 7-inch high by 10-35/64 inch wide chassis was established for all chassis other than power supplies. This chassis was also used to house groups of power-supply modules. A 22-1/8 inch long by 7-inch high by 6-13/16 wide chassis was designed for smaller power supplies. Three power-supply chassis lengths were established so that the following three combinations of power supply modules could be accommodated:

a. Three small power supplies

b. One medium-sized power supply and one small power supply

c. One large power supply

On chassis other than power supplies, provisions were made at the rear of the chassis for mounting component boards containing non-transistorized circuits such as filters. Provisions were incorporated at the front of each chassis for adjustment controls, test points and indicator lamps. The positions of these items were standardized to reduce design and fabrication costs.

Pendant cables were considered in the design of the chassis but this design was discarded because of the cost. Chassis keying devices were incorporated to prevent the insertion of a chassis into the wrong location. Both left-handed and right-handed chassis were designed in order to allow access to the cards and to the base of each chassis when the chassis is withdrawn for maintenance. A card retaining rod was incorporated into the chassis design.

1.1.7.3.3 RACK DESIGN - A standard, commercially available rack structure was utilized for this cabinet. The dimensions are 77-1/8 inches high by 34-9/16 inches wide by 25-1/2 inches deep. The width was established in accordance with the dimensions of the chassis previously described in order to allow two plug-in card chassis and one power-supply chassis to be mounted in one horizontal row. The small power-supply chassis are mounted between two printed-circuit card chassis.

Vertical panels were incorporated to direct cooling air up through each vertical column of chassis. A rear vertical panel was included for mounting connector plates. Parts such as the rear connector plates were standardized to reduce production costs. A connector panel was incorporated at the bottom of the cabinet for interconnection with other cabinets.

A rear hinged door was incorporated to provide access to cabling at the rear of the connector plates. No front door was provided, since the front panels of some of the chassis contain test points.

1.1.7.3.4 COOLING - Two flat three-bladed fans were provided at the bottom of the cabinet. A filtered air inlet is located at the bottom and a filtered air outlet is located at the top. The top filter prevents dust from entering the cabinet while the Conditioner-Generator Unit is turned off.

1.1.7.4 RECOMMENDATIONS

1.1.7.4.1 COMPONENT MOUNTING - Standardization of card size and provisions for mounting of non-transistorized circuit components appears to be satisfactory in this system. A further investigation of circuit design and optimum

Figure 10. Conditioner-Generator Unit, Rear View

component numbers per card might result in a slightly different card size as an optimum.

1.1.7.4.2 CHASSIS DESIGN - It appears that in any future production, complete modularization of the chassis would not be the optimum design for this system. Now that the circuit requirements have been established, it is recommended that in any future modification of the system, the chassis be constructed as bins in a single bay structure (see figure 11). This would reduce the number of connectors between chassis-level components, improve reliability, and reduce maintenance problems. A single pendant cable at the rear of a slide-out (see figure 12) appears to be the optimum design. Each bay would then contain the power supplies most directly related to it, thus reducing the number of connections in the power system. In this configuration, adjustment controls and test points should be located on the bay behind a closed door. This door would be opened only to gain access to important adjustment controls, test points, and indicators. There would be no need for a rear door, since all components and connections would be accessible from the front and would be hidden by a door.

1.1.7.4.3 RACK DESIGN (see figure 12) - Use of standard commercial racks proved to have one major drawback; i.e., the rack selected was insufficiently rigid to contain the individual chassis properly. A source of sturdier racks has since been discovered and this source should be utilized in the future.

1.1.7.4.4 FINISH - The problem of special finish on the exterior of the racks resulted in a great deal of unnecessary expense. It is recommended that a less critical paint specification be required in any future system.

1.1.7.4.5 INTER-CABINET CONNECTIONS - Inter-cabinet connections should be moved to the top of the cabinet because the cable runs in most field installations will be above rather than below the cabinets. Utilization of the bay construction will reduce the number of additional structural members required for the rack, resulting in a lower cost for fabrication.

1.1.7.4.6 COOLING - The fan specified by the prime contractor has proved to be inadequate for movement of air in this unit. It is recommended that a centrifugal blower be used in place of the fan. Inlet and outlet locations appear to be satisfactory, except for the problem of blockage of air through the top exit. The possibility of expelling air through the sides should be investigated.

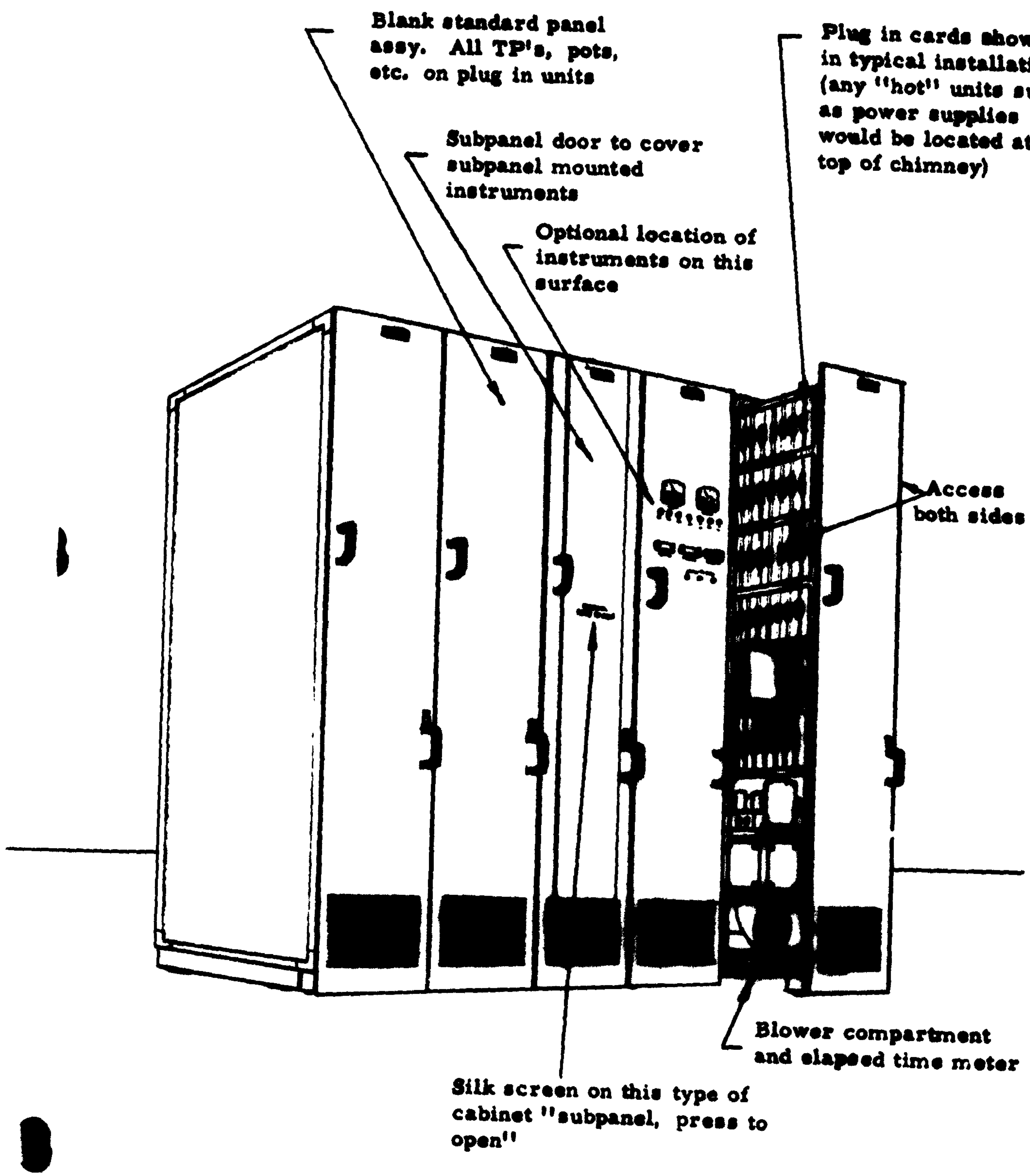


Figure 11. Recommended Bay Structure Utilizing Bin-Type Chassis Modules

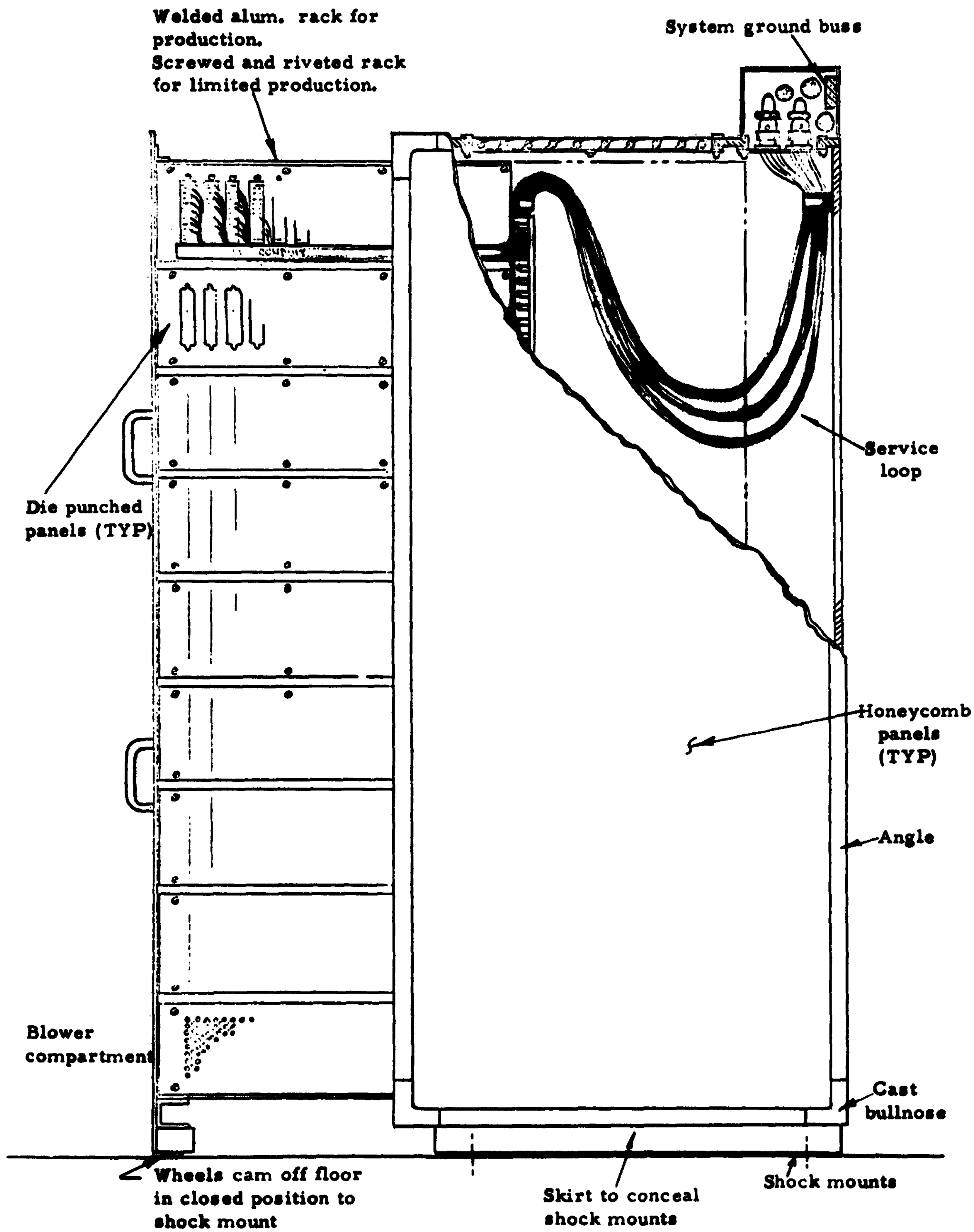


Figure 12. Recommended Rack Structure

1. 2 VIDEO TRACKER UNIT (see figure 13)

1. 2. 1 VIDEO TRACKERS (see figure 14)

1. 2. 1. 1 DESIGN OBJECTIVES

The Trackers must perform the following operations:

a. Accurately determine the position and altitude of an aircraft using the outputs of a scanning radar or beacon interrogator. The information is to be used for computers and displays.

b. Maintain track of a target so that the controller may easily identify and follow the target.

c. The Trackers must track targets anywhere within a 100 nautical mile radius of the radar antenna and at any altitude up to 100,000 feet.

d. The Trackers must operate from any one of three radar videos (MTI, normal or integrated) and from whatever beacon data is presented.

e. When altitude data is not available from the radar or beacon, the Trackers must operate in two dimensions.

f. The Trackers must be capable of operating in either an automatic (track-while-scan) mode or a coast mode.

g. Provision must be made for manual control and slewing of Trackers and for manual rate-aided tracking.

h. Any Tracker must be capable of being assigned to any controller and the Trackers must be installed at a position remote from the controllers and their displays.

1. 2. 1. 2 DESIGN ALTERNATIVES

a. Digital, analog or hybrid circuits can be used for the Trackers.

b. The tracking may be performed in cylindrical or Cartesian coordinates

c. The controls may be time-shared or switching can be provided in each Tracker to connect it to any one of the displays

Figure 13. Video Tracker Unit

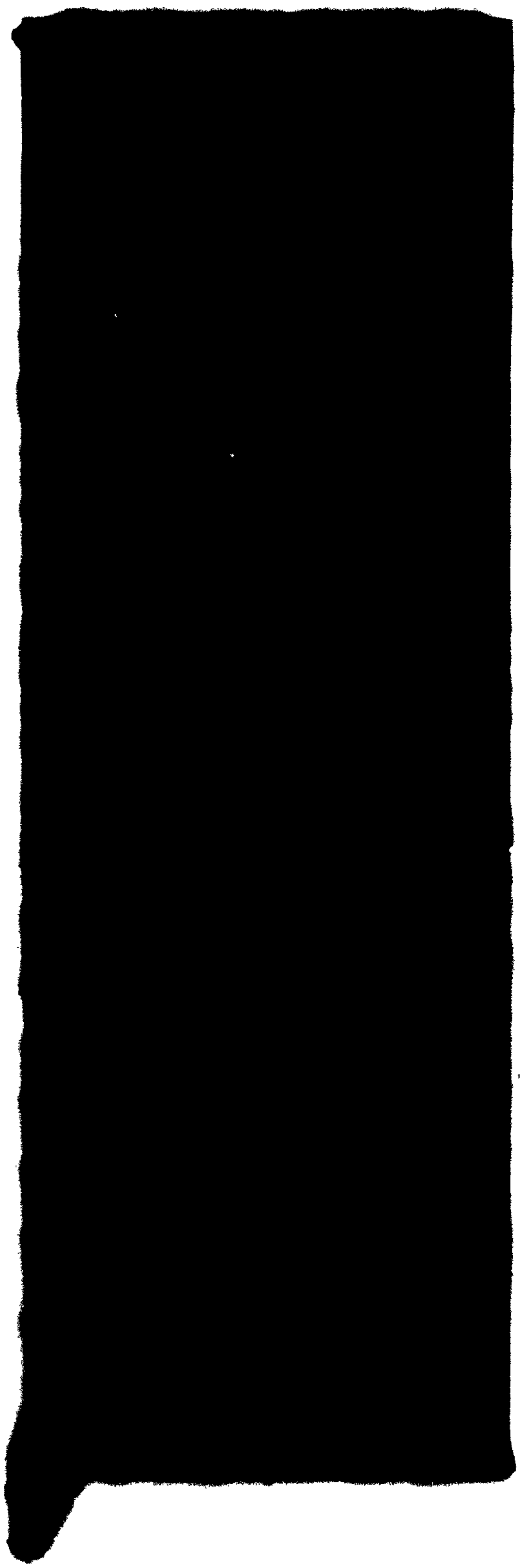


Figure 14. Video Tracker

1.2.1.3 FINAL DESIGN

1.2.1.3.1 CHOICE OF FINAL DESIGN

a. Analog circuits were selected for the Trackers because the accuracies required for digital circuits would have necessitated digital clock rates near the limit of the state of the art at the time.

b. Cartesian coordinates were selected rather than range and angle coordinates because Cartesian coordinate tracking has no discontinuity in angle, permits linear target prediction, and results in identical design for the x and y tracking channels. X and y data from the Tracker is also more easily used by the computers and displays.

c. Time-shared control was selected rather than switching because this minimized the number of wires which must be run from the display and control area to the equipment room, and resulted in considerably less equipment than would be required for a continuous switching network.

1.2.1.3.2 DESCRIPTION OF FINAL DESIGN (see figures 15 and 16)

1.2.1.3.2.1 NORTH-SOUTH AND EAST-WEST TRACKING CHANNELS - The N-S and E-W tracking channels are identical (see figure 15). Each channel consists of an error detector and a velocity and position storage circuit. The error detector is of the type which determines the distance in the particular coordinate from the predicted position of the target as represented by the stored position voltage to the center of gravity of all target hits within the gate. A fraction of this distance is then inserted into the position memory as a position correction and a proportional correction is inserted into the velocity memory. The velocity memory is integrated continuously by the position memory to generate the target position prediction.

1.2.1.3.2.2 ERROR DETECTOR - Since the radar and beacon sets are not necessarily co-located, separate sweeps must be generated for each. The Tracker must operate with the correct set of sweeps, depending upon the video which it is tracking. A relay switches between the radar sweep and the beacon sweep at the front of each channel in the Tracker. The selected sweep is then compared with the stored position voltage representing the predicted position of the target.

A push-pull difference signal is generated by a differential amplifier. This push-pull difference signal is linear over a range of approximately ± 2 1/2 miles on either side of the predicted target position. Since the tracking gate is never this large, the fact that the difference signal is non-linear beyond this range is not of significance. The push-pull difference signal is used for two purposes. It is sent

to a diode selection circuit which selects the more positive half of the push-pull signal. This results in a triangular-shaped waveform each time the sweep crosses the position voltage. The triangular waveform is amplified and compared against a d-c level, the gate size voltage, which results in a tracking gate in the particular dimension associated with the particular channel. The gate is ANDed with the gate from the other channel and is used for video gating as described below.

The push-pull difference signal is also used in the error sampler. In this circuit, the difference signal is sampled at the time of a video pulse. The result is push-pull amplitude-modulated error pulses. The difference between these error pulses represents the instantaneous error for that particular video hit. The error pulses are amplified and summed in two capacitors. Thus, the difference between the voltages on the capacitors, after all pulses have arrived, is the sum of the errors measured for each of the individual video pulses. This sum is equal to the average error times the number of hits. The difference voltage decays with a known time constant and, at the instant when it has decayed to the level proportional to three hits, i. e., a constant times the average error, the signal is switched into the position storage circuit and a proportional signal is switched into the velocity storage circuit. The timing circuit which throws the switch is described later.

1. 2. 1. 3. 2. 3 STORAGE CIRCUITS - The position and velocity storage circuits each consist of a Miller integrator with very low leakage rate. The low leakage is obtained by using Mylar storage capacitors, electrometer tube input stages in the amplifiers, relays to enter the high-impedance point at the input of the Miller amplifiers, and then potting all components touching the high-impedance point in an epoxy unit. The amplifiers are high-gain operational type amplifiers, transistorized after the first electrometer tube stage. There are two external inputs to the amplifiers. The automatic correction enters through the automatic correction relay as described above, and is connected differentially between the velocity and position memories. The relay remains closed for a long time relative to the time constant necessary to discharge the error averaging capacitors which hold the correction signal. Thus, these capacitors are completely discharged into the storage capacitors. The same charge is applied to both the velocity and the position storage capacitors. The scale factor in the two cases is taken into account by the difference in the sizes of the velocity and position capacitors. The second input accounts for all slewing of the storages by waiting points and by controller slewing. This input to each channel is through another relay, the slewing correction relay, and additionally switched by an electronic switch in front of the relay which accomplishes the time-sharing function. Velocity is also integrated through a large resistor to the position storage amplifier. An external circuit is provided for connecting capacitors in parallel with the velocity memory capacitor. This changes the ratio of velocity to position automatic correction when it is desirable to do this due to unusual radar rpm and signal-to-noise ratio. The outputs from the position storage circuits may be taken directly or may be time shared in either of two sequences for which electronic switches are provided. These are the compute sequence and the slew sequence. A relay is also provided to short the storage

capacitors and return the amplifiers to zero. This occurs when the Tracker is in pool and consequently this relay is known as the pool relay.

1.2.1.3.2.4 Z (ALTITUDE) CHANNEL - The circuits of the altitude channel are almost identical to the circuits of the North-South and East-West channels. The difference lies in the front end of the error detector where a few components have been changed to improve transient response. The storage amplifier circuit is exactly identical with North-South and East-West channels. The reference waveform at the input channel is an amplitude modulated pulse instead of a sweep. Consequently, waveforms in the early part of the error detector are considerably different from waveforms in the other channels. However, the function of the circuit is the same. The amplitude modulated pulse is compared with the stored altitude, and push-pull error waveforms are developed. These do not form sloping lines but rather only instantaneous values during the altitude pulse. The gate is generated by the same circuit as in the other channels but it will be open only during the altitude pulse. Error sampling is exactly the same as in the other channels.

1.2.1.3.2.5 VIDEO SWITCHING AND GATING - The desired video is selected when the controller pushes the VIDEO select button on his Tracker Control Panel. This causes a positive-going pulse to enter the Tracker through time-sharing gates and set a flip-flop. Simultaneously, a reset pulse is generated which turns off any previously selected video flip-flop. One flip-flop per type of video was selected rather than a register and decoding matrix because of the relative cost of the two techniques for the five or six videos involved. The selected video opens a gate which permits that video to enter the Tracker circuits. The selected video is one of two kinds, 2-D or 3-D. If it is a 2-D video, it must also be passed by a signal which indicates that the Tracker x-y gate is present and that the automatic tracking mode has been selected. The 2-D video then goes to the North-South and East-West channels and to the 2-D division circuit to be discussed later.

The 3-D video, in addition to being gated as described above, is also gated by the altitude gate before going to the tracking channels. An altitude search mode is provided which may be selected by the controller when he presses his Large Z Gate button. This bypasses Z gating of the video and allows the Tracker to search in altitude. It also causes the Z velocity memory to be shorted so that a large velocity is not generated during search. Other circuits also detect whether a radar video or a beacon video is selected. These activate the relays which switch between radar and beacon sweeps and also switch the tracking gate to the radar or beacon gate bus for display purposes. The selected video is also indicated on the controller's Tracker Control Panel by time-shared output signals which indicate which flip-flop is on. These are time-shared in the same sequence as the inputs.

1.2.1.3.2.6 TRACKER MODE SELECTION - Three tracking mode flip-flops and a latching relay are provided. These are the tracking mode flip-flop which selects between automatic track and coast, the Z gate flip-flop which selects between small Z gate and the large Z gate search mode, the pool flip-flop which selects between tracking operation and Tracker-in-pool condition, and the maintenance latching relay which switches between normal operation and maintenance condition in which the Tracker may not be used. All of these are controlled by time-shared input signals, and present status is indicated to the controller by time-shared outputs.

1.2.1.3.2.7 DIVISION CIRCUITS - The gated 2-D video pulse is fed to a pulse amplifier and then to a Schmidt trigger circuit. The input to the Schmidt trigger circuit has a diode capacitor arrangement which generates an analog stairstep for each video pulse. On the third pulse the Schmidt trigger is armed. The diode and capacitor continue to add up the video pulses as long as there are pulses arriving, but the capacitor discharges with a time constant matched to the time constants in the error summing circuits described above. When this voltage has decayed to the level of three hits, the Schmidt trigger returns to its original state. This is detected and used to fire the automatic correction relay for about 20 milliseconds. The time which the Schmidt trigger takes to fire the automatic correction relay will be a function of the number of hits and it will vary in just such a fashion as to divide the correction by the number of hits. An identical circuit operates from the 3-D video to operate the Z automatic correction relay. When operating with a 3-D radar, the circuit for the North-South and East-West automatic correction relays also operates with the 3-D video.

1.2.1.3.2.8 OFF TARGET DETECTION - Two off-target detector circuits are provided, one for North-South - East-West and one for Z. These detect when a correction has not occurred for a certain length of time which is adjustable from about 3 to 25 seconds. The absence of an automatic correction in this period is taken to mean that the Tracker is off target. This circuit is an r-c integrator and a detector with a reset circuit. If an off-target indication occurs, this has several effects. It causes the status signal pulse which lights the associated status lamp on the Tracker Control Panels to blink. It sends a signal to the Video Track Programmer which causes a bar to be printed over the associated Character Block, and it also sends signals to the gate size adjustment circuits to increase the Tracker gate size.

1.2.1.3.2.9 TRACKER GATE SIZE - Gate size voltages, which control the normal tracking gate size for radar and for beacon and also expand the gate with range, come from the Conditioner-Generator Unit. In the Tracker, these voltages are modified depending upon the history of the particular Tracker. First, the radar gate size voltages or the beacon gate size voltages are selected by electronic switches. These electronic switches are driven by the same signal which selects

radar or beacon sweeps for the tracking channels. After the correct gate size voltage is selected for North-South and for East-West, they are then fed to function generators which modify them according to the track history. If tracking is normal, the voltages are divided by two, resulting in the small gate size. If the Tracker is indicating off target, the voltages are not divided and this results in the large gate size, which is exactly twice the small gate size, except that the gate size is limited to 4 miles. This is done separately for North-South and for East-West, since the two gate sizes need not be identical. When video is again received after an off-target indication, the first correction causes the gate to go to an intermediate size, half way between the small size and the large size so that this intermediate size is seen on the next scan after the first correction. If the second correction is then received, the Tracker gate size will again go to normal minimum size.

1. 2. 1. 3. 2. 10 TIME SINCE LAST CORRECTION - A Miller integrator keeps track of time-since-last-correction. This integrator can run for five minutes. Any time that a correction is received, either automatic or manual, the integrator is reset to zero. Thus, time-since-last-correction may be anything between zero and five minutes. After five minutes, the amplifier saturates. Because of the long time involved, an electrometer tube is used for the first stage of the amplifier. The output time-since-last-correction signal is time shared in the slew sequence by an electronic switch and fed to the Waiting Point Generator.

1. 2. 1. 3. 2. 11 TIME SHARING - Two time-sharing sequences are provided in the Tracker. The first is the slew sequence. In this sequence, the Trackers selected on the ten sets of Tracker Control Panels are selected and tied to the time-shared lines, one after another. Repeating at a 60-cycle rate, each one is connected for 1. 6 milliseconds at a time. The Tracker is connected to the bus by the coincident arrival of a Selected Tracker On pulse and an Assigned Tracker pulse from the Video Track Programmer. These set the selected Tracker flip-flop. The flip-flop is turned off 1. 6 milliseconds later by a Selected Tracker Off pulse from the Video Track Programmer. This time-sharing sequence controls all logical inputs to the Tracker, all the lamp indication outputs, time-since-last-correction voltage, time-shared outputs, and the slew spot voltage time-shared outputs from the tracking channels. The sequence is also used for waiting point slewing, in which case the Tracker is connected for 50 milliseconds instead of 1. 6 milliseconds.

The other time-sharing sequence in the Tracker is the compute sequence. This follows no set time pattern and is controlled by the Video Track Programmer. The outputs which are time-shared by this sequence are four logical outputs, two of which are used by the Video Track Programmer and two of which are not used, and the time-shared output voltages from the tracking channels for purposes of character and circle print on the PPDD.

1. 2. 1. 3. 2. 12 MAJOR PROBLEMS AND SOLUTIONS

a. It was necessary to develop a circuit which could compare the sweep with the stored position voltage to an accuracy of 10 millivolts or better. The circuit must not be damaged by 40 volts of difference between the signals and must maintain accuracy with up to 40 volts of common-mode signal. Inverting one of the signals and using resistive subtraction was considered. This eliminates the common-mode problem. With reasonable input impedances to the detector circuit, however, the resistances had to be extremely low in the resistive subtractor and this resulted in an extremely difficult problem in driving the sweep into 50 of these circuits in parallel. Therefore, this technique was rejected. Instead, a transistor differential amplifier was adopted. Using silicon transistors, the common-mode rejection could be made very good. By using low current in the stage, very little heating effect resulted from the large voltage swings, so slump was not a serious problem. Recent availability of silicon transistors with high beta at low collector currents made this circuit possible. Frequency response and voltage of the transistors was also important because of the large voltage swing and because of the high accuracy required with the transient signals involved.

b. A correction factor independent of target blip size was wanted for any target size between 3 and 100 hits. This means that the correction must be divided by a number which varies in the ratio 33:1. This presents considerable difficulty in maintaining accuracy in the divider while working over this wide range, and because the voltage before division may be 33 times the largest correction ever expected. This limits the voltage scale of the correction and consequently makes it subject to small drift voltages. The mechanics of the circuit adopted have been described earlier (1. 2. 1. 3. 2. 7). The voltage problem was partially overcome by using high-voltage silicon transistors and a voltage swing in the correction circuit of about 50 volts. This allows a maximum correction after division of about 1 1/2 volts or about 4 times greater than the voltage scale at the output of the storage circuits.

c. There are two kinds of storage amplifier drift which can cause problems. One is the drift of the integrator as a whole due to leakage of some element to the error point of the amplifier. This causes a ramp-like charging of the storage capacitor. This was avoided in this case by using an electrometer tube as the input stage of the amplifier, using only high impedance elements to touch the error point, and potting all of the elements within a single epoxy unit. The electrometer tube chosen, which was the only suitable subminiature electrometer available, is highly microphonic and non-repeatable, i. e., the anode voltage changes after the equipment is turned off and then turned on again. Consequently, there is considerable difficulty in keeping the amplifier itself zeroed. This is the second type of drift. The results of this type of drift are that a false correction is introduced into the tracking circuits. Since the correction voltages are at a scale about four times greater than the output voltage as described above, drift of the amplifier's zero point introduces only about one-fourth as much error in the Tracker output. However, to overcome the non-repeatability of the tubes after

turn-on and vibration, potentiometers were placed on the front panel of the Tracker for adjustment without removing the Tracker from the cabinet.

1. 2. 1. 3. 2. 13 ENGINEERING CHANGES

a. During the first two years of the contract, the height information format was not well defined. Final design on the Z channel was therefore held up until late in the contract. The x-y amplifier channel design was adopted with some change in circuit elements to obtain better transient response.

b. There was considerable delay in defining the beacon video input to the Video Tracking system. This resulted in several redesigns of the beacon video handling procedure in the Tracker. Circuit requirements changed and consequently the design changed because of relaxing the waveform requirements on the Beacon Z video.

c. A circuit was added to provide a signal to the Video Track Programmer so that a bar or a half bar might be printed when the Tracker was in the manual coast or off-target condition. This caused the addition of several electronic switches in the Tracker.

d. The Tracker was modified so that a slew dot would be printed at all times when the Tracker was selected rather than just when the button on the slew control was activated. This caused a minor change in the Tracker circuits.

e. A circuit was added to provide readout of the beacon gate on a 75-ohm line for the purpose of beacon code acquisition.

f. The maximum time to indicate off target was increased from 15 to 25 seconds. This was accomplished by increasing a capacitor size. However, due to the limited space, it was necessary to use a special capacitor for this purpose.

1. 2. 1. 4 RECOMMENDATIONS

1. 2. 1. 4. 1 DIGITAL OR HYBRID TRACKERS - Digital or hybrid Trackers should be considered. These appear particularly attractive for the Z channel, since the data could be made available conveniently in parallel digital form from the altitude gathering devices.

1. 2. 1. 4. 2 FEWER VIDEO SOURCES - Reduction of the number of videos which may be selected should be considered. It may be impractical to track on a video which the controller can not directly observe. Since he can observe essentially only one radar video and one beacon video at any time, it may not be practical to have more than these options available to the Tracker.

1.2.1.4.3 MEMORY AMPLIFIER - An improved memory amplifier should be considered. The variable-capacitance ring-modulator type of amplifier appears to be particularly attractive.

1.2.1.4.4 TRACKER ADJUSTMENTS - Techniques should be studied for reducing the number of adjustments in the Tracker and the frequency which is required for these adjustments.

1.2.1.4.5 BEAM-WIDTH RANGE - The present beam-width range of 3 to 100 hits results in a considerable cost in the Tracker, both in terms of price and performance. In view of the improved beacon sets which are becoming available, the ratio should be reconsidered.

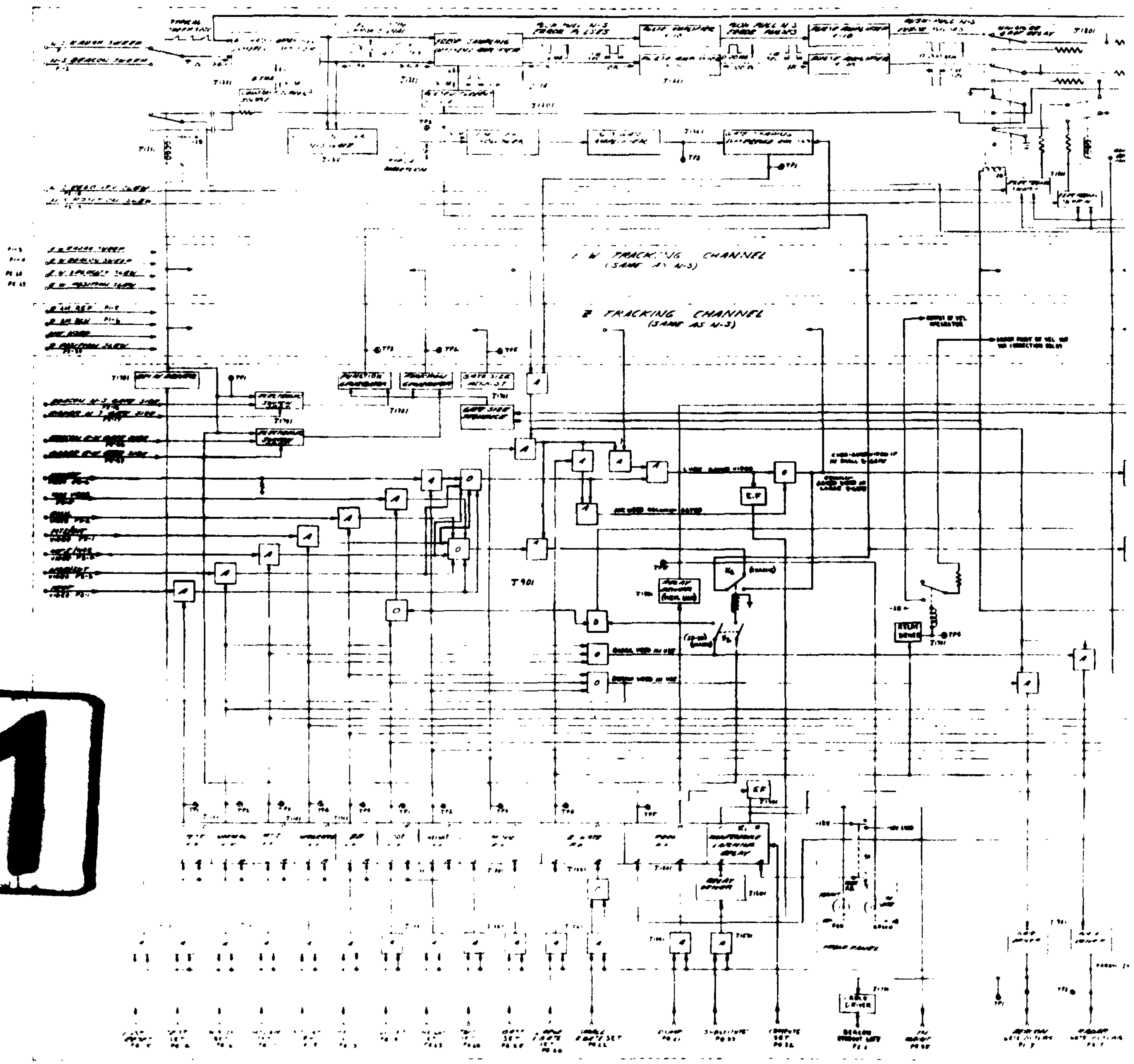
1.2.1.4.6 CO-LOCATION OF RADAR AND BEACON SETS - A very high price is paid throughout the Video Tracking System and the display system by the use of non-colocated radar and beacon sets. The advantages of colocation, particularly with 3-D radar, should be reconsidered in terms of the cost, reliability, and circuit complexity inherent in the use of separated antennas.

1.2.1.4.7 CHANGE OF LOGIC LEVELS - Converting the Trackers from positive logic to negative logic should be considered. While this will result in a slightly higher number of components, it will improve reliability especially against transient power failures.

1.2.1.4.8 AUTOMATIC COAST - A clutter rejection circuit which would inhibit correction in the Tracker when the number of hits received is greater than a preset maximum, would prevent a Tracker from locking on to clutter. That is, it would provide automatic coast in clutter areas.

1.2.1.4.9 OVERLAP PROTECTION - A circuit which will prevent corrections entirely when two tracking gates overlap, or when video appears in the overlap region, would prevent possibilities of target swapping and erroneous velocities. These can occur with the present method of merely blanking the video. It would however, require a circuit in every Tracker.

1


E-W TRACKING CHANNEL
(SAME AS N-S)
E TRACKING CHANNEL
(SAME AS N-S)
T901

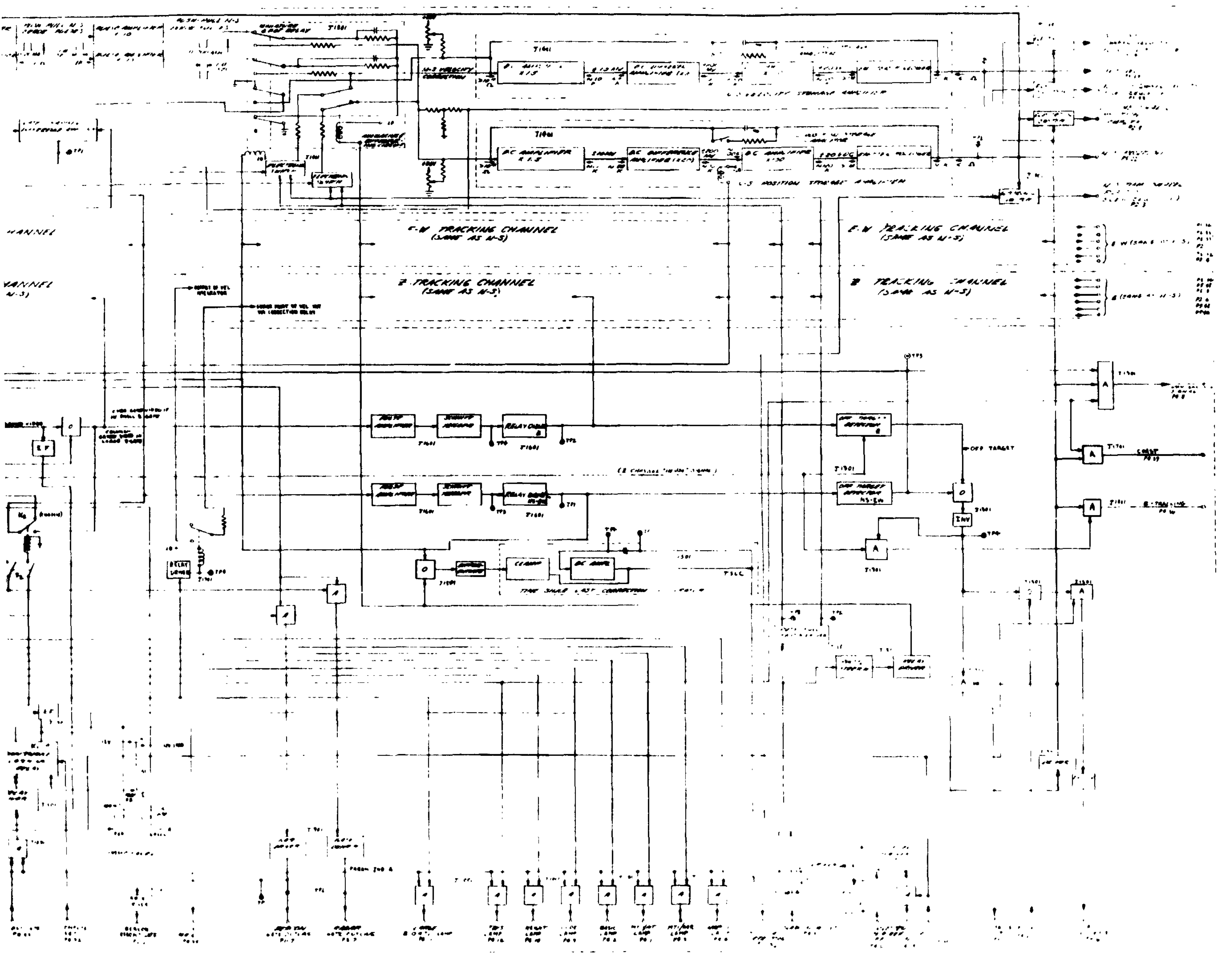
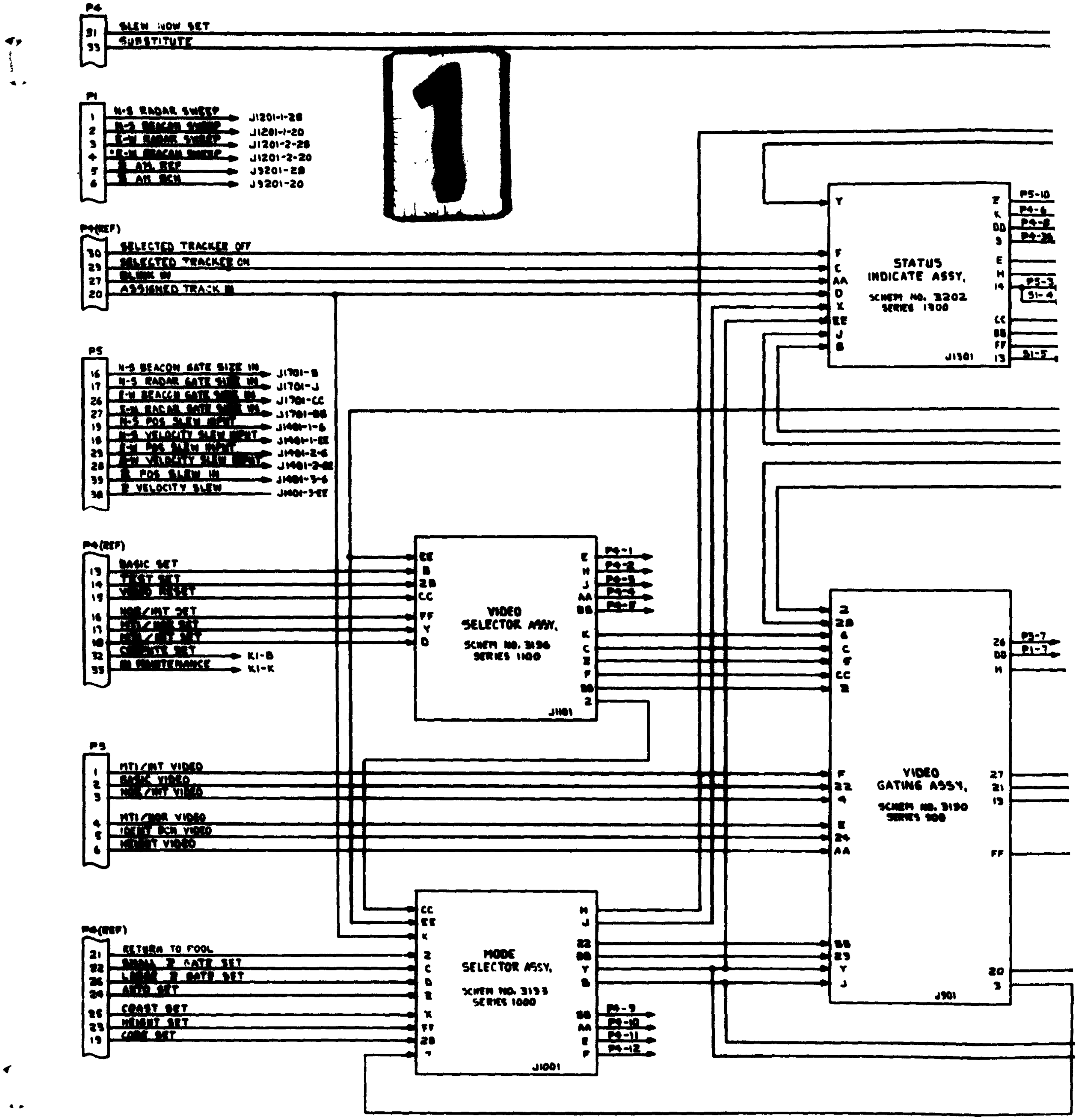


Figure 15. Video Tracker, Logic Diagram


P4
SLEW NOW SET
SUBSTITUTE
1
P1
N-S RADAR SWEEP
J1201-1-28
J1201-1-20
J1201-2-28
J1201-2-20
J3201-28
J3201-20
P4(REF)
SELECTED TRACKER OFF
SELECTED TRACKER ON
ASSIGNED TRACK IN
P5
N-S BEACON GATE SIZE IN
J1701-B
J1701-J
J1701-CC
N-S POS SLEW INPUT
Z POS SLEW IN
Z VELOCITY SLEW
STATUS
INDICATE ASSY,
SCHEM NO. 3202
SERIES 1300
J1301
P5-10
P4-6
P5-3
S1-4
S1-5
P4(REF)
BASIC SET
TEST SET
K1-B
K1-K
VIDEO
SELECTOR ASSY,
SCHEM NO. 3196
SERIES 1100
J1101
P4-1
P4-2
P4-3
P4-4
VIDEO
GATING ASSY,
SCHEM NO. 3190
SERIES 900
J901
P5-7
P1-7
P3
MTI/INT VIDEO
BASIC VIDEO
NOR/INT VIDEO
MTI/NOR VIDEO
IDENT BCN VIDEO
HEIGHT VIDEO
P4(REF)
RETURN TO POOL
AUTO SET
COAST SET
HEIGHT SET
CODE SET
MODE
SELECTOR ASSY,
SCHEM NO. 3193
SERIES 1000
J1001
P4-9
P4-10
P4-11
P4-12

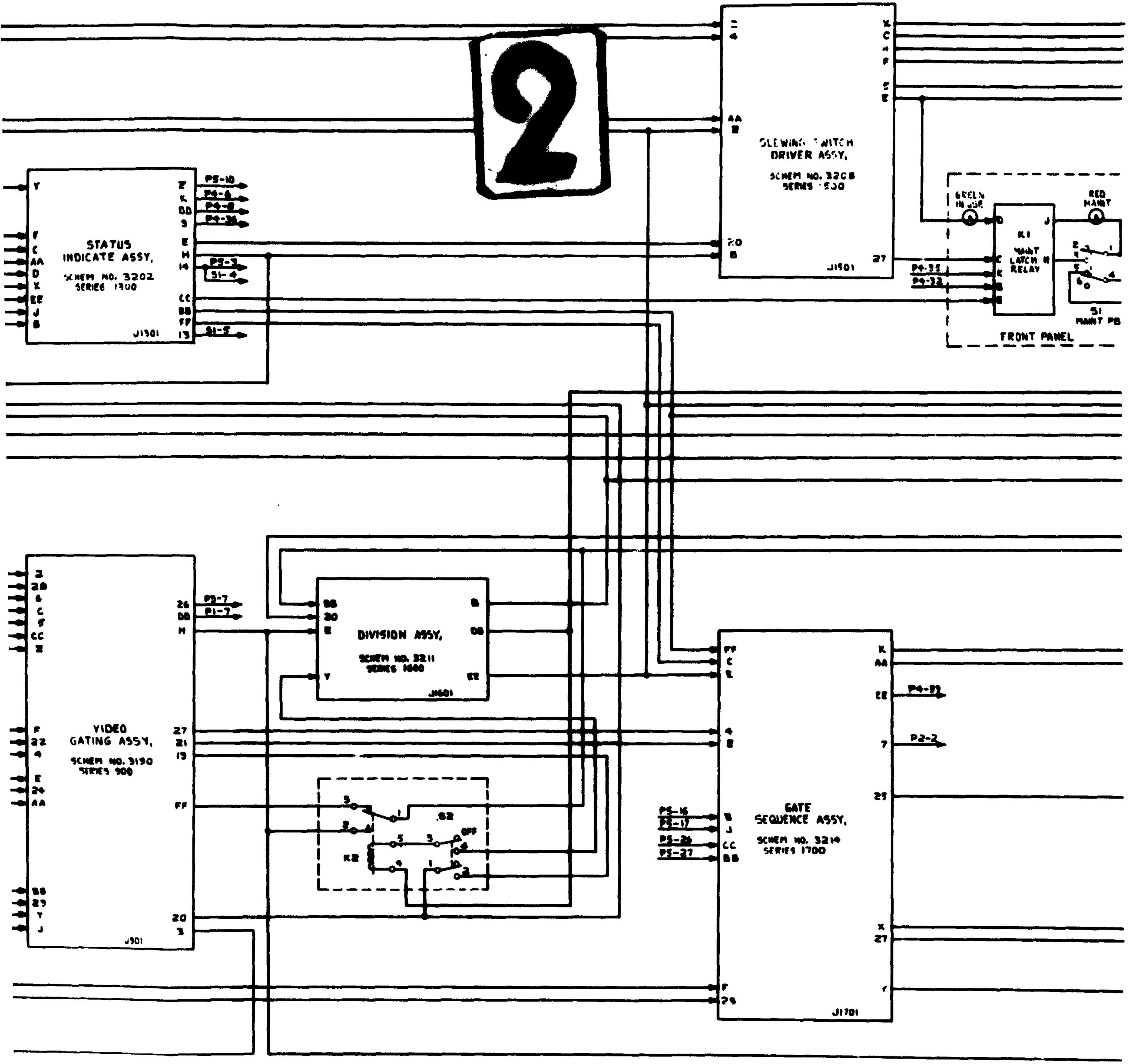
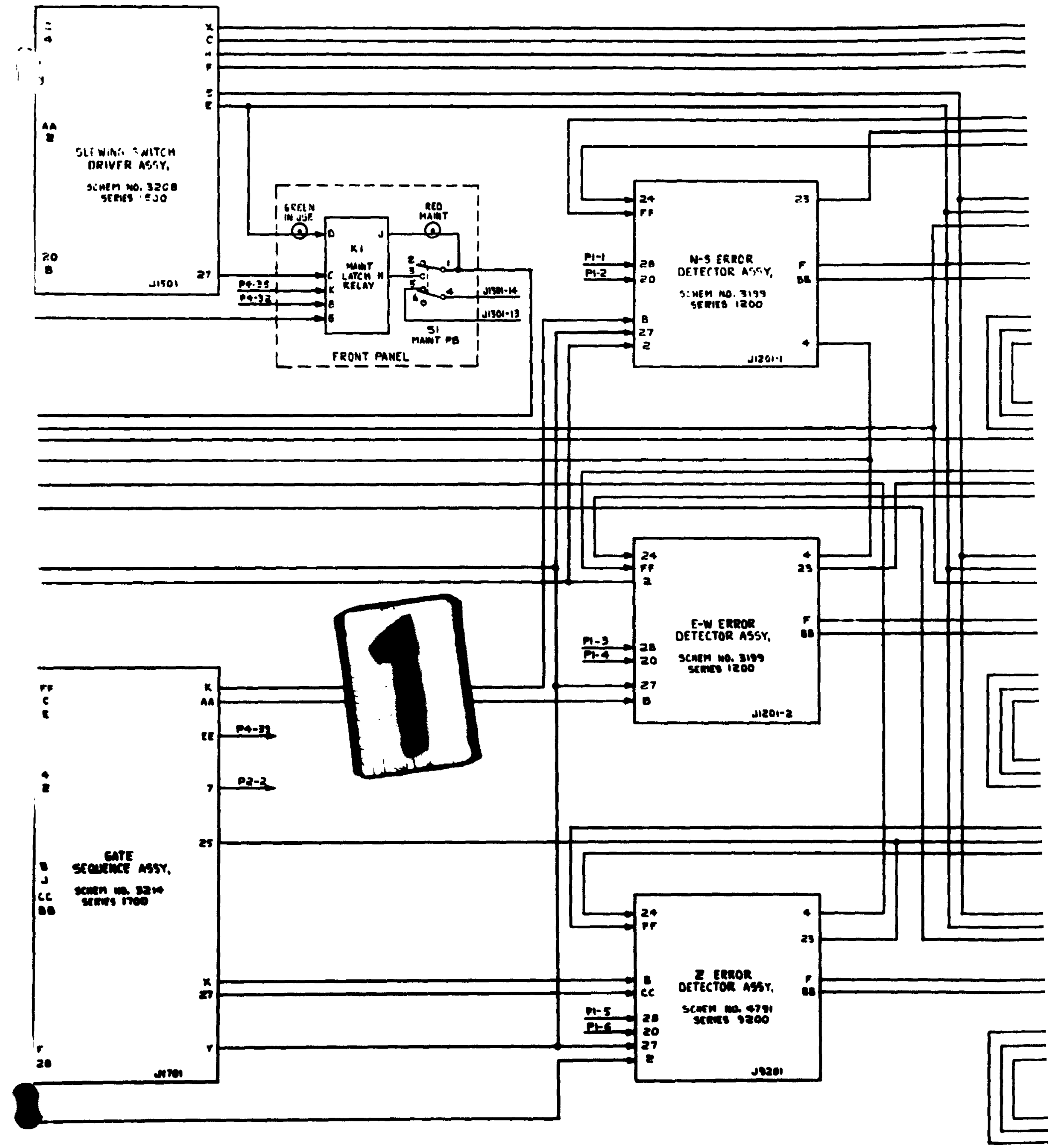


Figure 16. Video Tracker, Block Diagram

Sheet 1 of 2



SLEWING SWITCH DRIVER ASSY,
SCHEM NO. 3208
J1501
GREEN IN USE
RED MAINT
K1 MAINT LATCH RELAY
S1 MAINT PB
FRONT PANEL
J1301-14
J1301-13
P4-35
P4-32
N-S ERROR DETECTOR ASSY,
SCHEM NO. 3199 SERIES 1200
J1201-1
E-W ERROR DETECTOR ASSY,
SCHEM NO. 3199 SERIES 1200
J1201-2
Z ERROR DETECTOR ASSY,
SCHEM NO. 4791 SERIES 9200
J9201
GATE SEQUENCE ASSY,
SCHEM NO. 3214 SERIES 1700
J1701
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P1-2
P1-3
P1-4
P1-5
P1-6
P4-31
P2-2
1

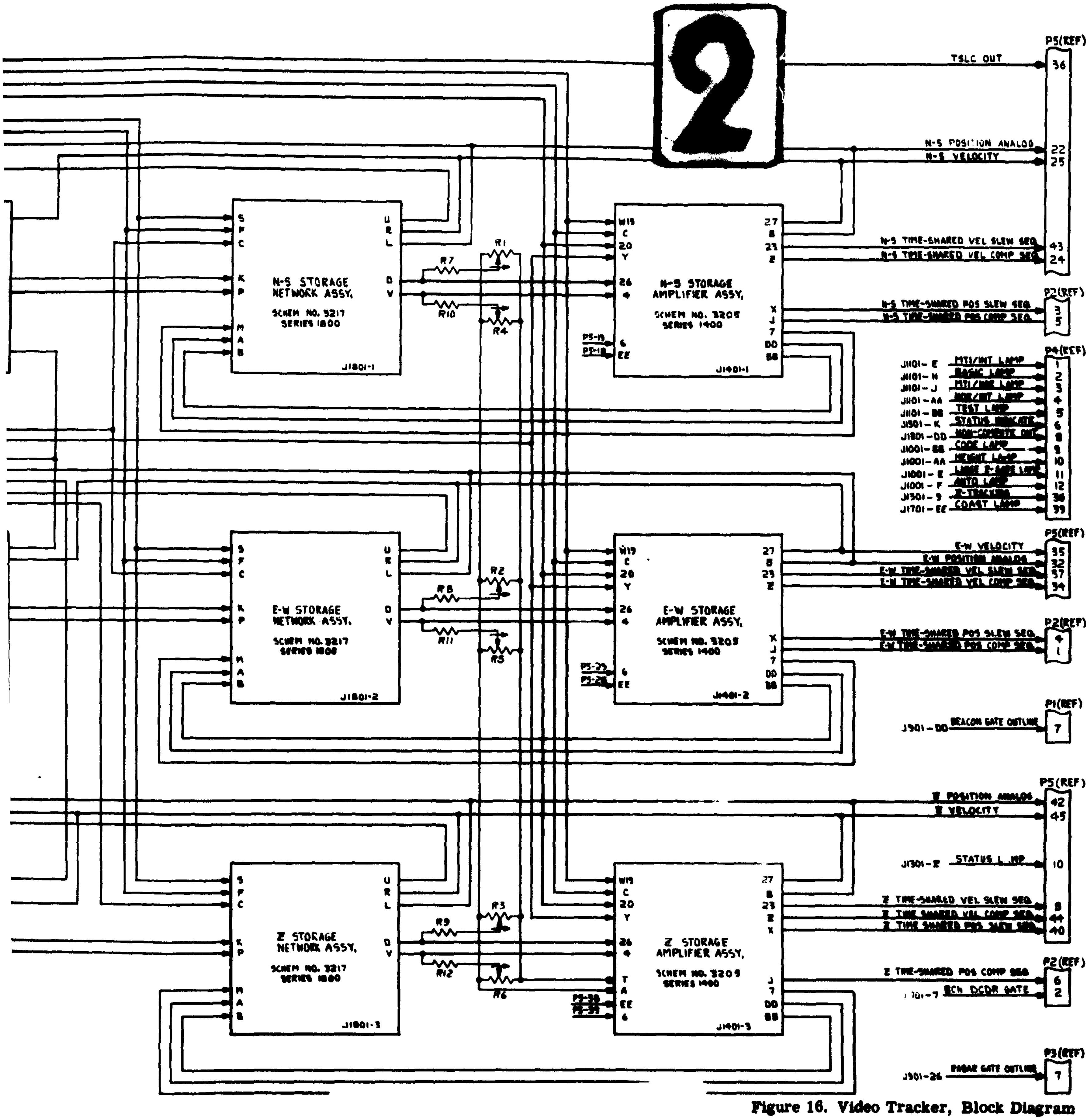


Figure 16. Video Tracker, Block Diagram

Sheet 2 of 2

1.2.2 VIDEO TRACKER UNIT POWER SUPPLIES

1.2.2.1 DESIGN OBJECTIVES

1.2.2.1.1 LOAD REQUIREMENTS - The load requirements for the Video Tracker Unit were as follows:

Volts DC	*Regulation	Ripple	Load (ma)
-45.0	±1.0%	±0.1%	500
-28.0	3.0	0.1	1000
-12.0	3.0	0.1	500
1.1	0.5	0.05	3000
1.5	0.5	0.05	100
24.0	1.0	0.1	1000
45.0	0.2	0.03	500

* No load to full load and ±10% input voltage variation

1.2.2.1.2 OTHER REQUIREMENTS - The design objectives given in paragraphs 1.1.6.1.2 through 1.1.6.1.9 for the Conditioner-Generator Unit power supplies are also applicable to the Video Tracker Unit power supplies.

1.2.2.2 DESIGN ALTERNATIVES

1.2.2.2.1 REGULATION - Magnetic, transistor, and vacuum-tube regulated supplies were considered as design possibilities. Other alternatives were the same as those of the Conditioner-Generator Unit power supplies (paragraph 1.1.6.2).

1.2.2.3 FINAL DESIGN

1.2.2.3.1 SELECTION OF FINAL DESIGN - Transistor-regulated power supplies were selected for reasons outlined in paragraph 1.1.6.3.1.

1.2.2.3.2 PURCHASED UNITS - Specifications were written, bids were advertised and contracts let to suppliers for the following final design units:

POWER SUPPLY	SPECIFICATION
1.25 vdc at 1.5 amp, ±0.5% reg	TES 1077
1.50 vdc at 0.2 amp, ±0.5% reg	TES 1078
12 vdc at 2.0 amp, ±3.0% reg	TES 1083
24 vdc at 0.5 amp, ±0.5% reg	TES 1086
24 vdc at 7.0 amp, ±3.0% reg	TES 1087
45 vdc at 1.0 amp, ±0.05% reg	TES 1089

1.2.2.3.3 PACKAGING - Power supply units were purchased to provide interchangeable assemblies as follows:

TIC Assembly	Module	Spec.	No. Required
3926			
	24 vdc ±0.2%	TES 1086	2
	45 vdc ±0.05%	TES 1089	2
3932	24 vdc ±3.0%	TES 1087	1
3956			
	1.25 vdc ±0.5%	TES 1077	1
	1.5 vdc ±0.2%	TES 1078	1
	12 vdc ±3.0%	TES 1083	1

1.2.2.3.4 TEMPERATURE STABILIZATION - To meet temperature stability requirements on the 45-volt d-c units, ovens were utilized to stabilize the Zener reference and difference amplifier circuits in the regulator feedback loop. Approximately 30 minutes stabilization time is required upon initial turn-on for these power supplies. Since continuous operation is contemplated, this is considered a tolerable restriction. Oven heat can be applied at all times, however, to reduce turn-on stabilization time to a minimum of two to three minutes or less.

1.2.2.3.5 CIRCUITS - Considerations outlined in paragraphs 1.1.6.3.4 also apply to the supply units designed for the Video Tracker Units. In addition, primary power is applied to the 1.25-volt d-c supply and the 1.5-volt d-c supplies in the Video Tracker Unit cabinet at all times, to provide continuous filament excitation for the Tracker electrometer vacuum tubes.

1.2.2.4 RECOMMENDATIONS

1.2.2.4.1 The recommendations given for the Conditioner-Generator Unit power supplies in paragraph 1.1.6.4 also apply to the power supplies of the Video Tracker Unit.

1.2.2.4.2 A lower voltage unit may be desirable in place of the 24-volt d-c, 7-ampere supply in order to reduce power dissipation in the Video Tracker Units. However, adjusting the output to the lowest obtainable voltage has resulted in lower dissipation while utilizing a common power supply design. This adaptation resulted in an excess of available load current but resulted in a unit having common characteristics with other system design requirements.

1.2.3 VIDEO TRACKER UNIT CABINET

1.2.3.1 DESIGN OBJECTIVES

The design objectives for the Video Tracker Unit cabinet were basically the same as the objectives for the Conditioner-Generator Unit cabinet (paragraph 1.1.7.1).

1.2.3.2 DESIGN ALTERNATIVES

The design alternatives for the Video Tracker Unit cabinet were basically the same as those of the Conditioner-Generator Unit cabinet (paragraph 1.1.7.2).

1.2.3.3 FINAL DESIGN

1.2.3.3.1 MOUNTING OF COMPONENTS - Mounting of components in the Video Tracker Unit cabinet is basically the same as for the Conditioner-Generator Unit Cabinet (paragraph 1.1.7.3.1).

1.2.3.3.2 CHASSIS DESIGN - The final design of the Tracker chassis was based on the requirement that the Video Tracker Unit contains up to 26 Trackers. The Trackers were not designed as both right-hand and left-hand chassis. Otherwise, chassis design for the Trackers is the same as for the chassis of the Conditioner-Generator Unit (paragraph 1.1.7.3.2).

1.2.3.3.3 RACK DESIGN - A standard, commercially available rack structure was utilized for the Video Tracker Unit cabinet. The Video Tracker Unit consists of two racks bolted together and interconnected by inter-rack cabling. The dimensions of cabinets are 77-1/8 inches high by 28-9/16 inches wide by 25-1/2 inches deep. The width was determined on the basis of the dimensions of the Tracker chassis. Each rack contains two vertical columns of Trackers and three small power-supply chassis at the top. The normal Video Tracker Unit consists of two of these racks bolted together at the sides and containing a total of twenty-five Trackers, with one empty bay covered by a blank panel. Special provisions were incorporated for mounting of multiple coaxial connectors.

Other design characteristics of the Video Tracker Unit cabinet are similar to those of the Conditioner-Generator Unit cabinet except that there is only one cooling fan in each rack.

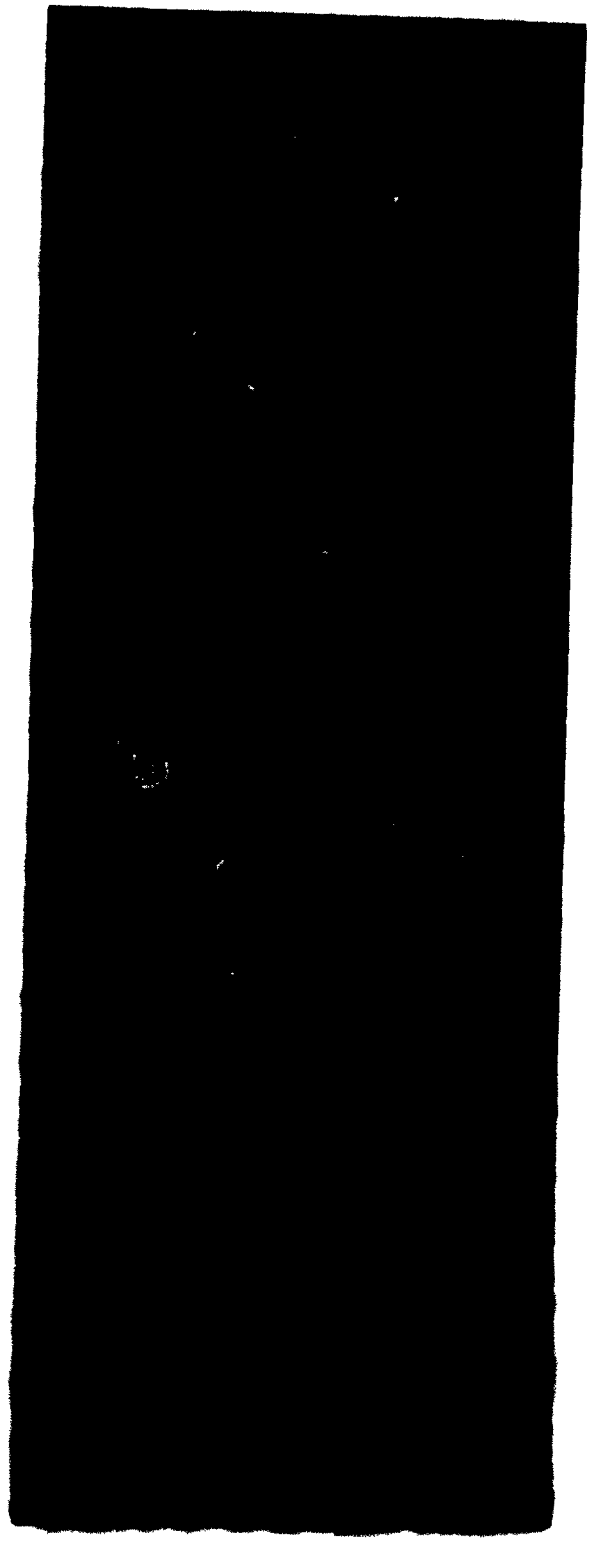


Figure 17. Video Tracker Unit, Rear View (1/2 Cabinet)

1.2.3.4 **RECOMMENDATIONS**

1.2.3.4.1 **CHASSIS DESIGN** - The modular design of the Trackers has proven satisfactory in that it is convenient to have one Tracker per chassis. No changes are recommended unless it is desired to incorporate the changes recommended in paragraph 1.1.7.4.2 for the Conditioner-Generator Unit Chassis. If so, modular sub assemblies can be mounted on a pull-out frame (see figure 18).

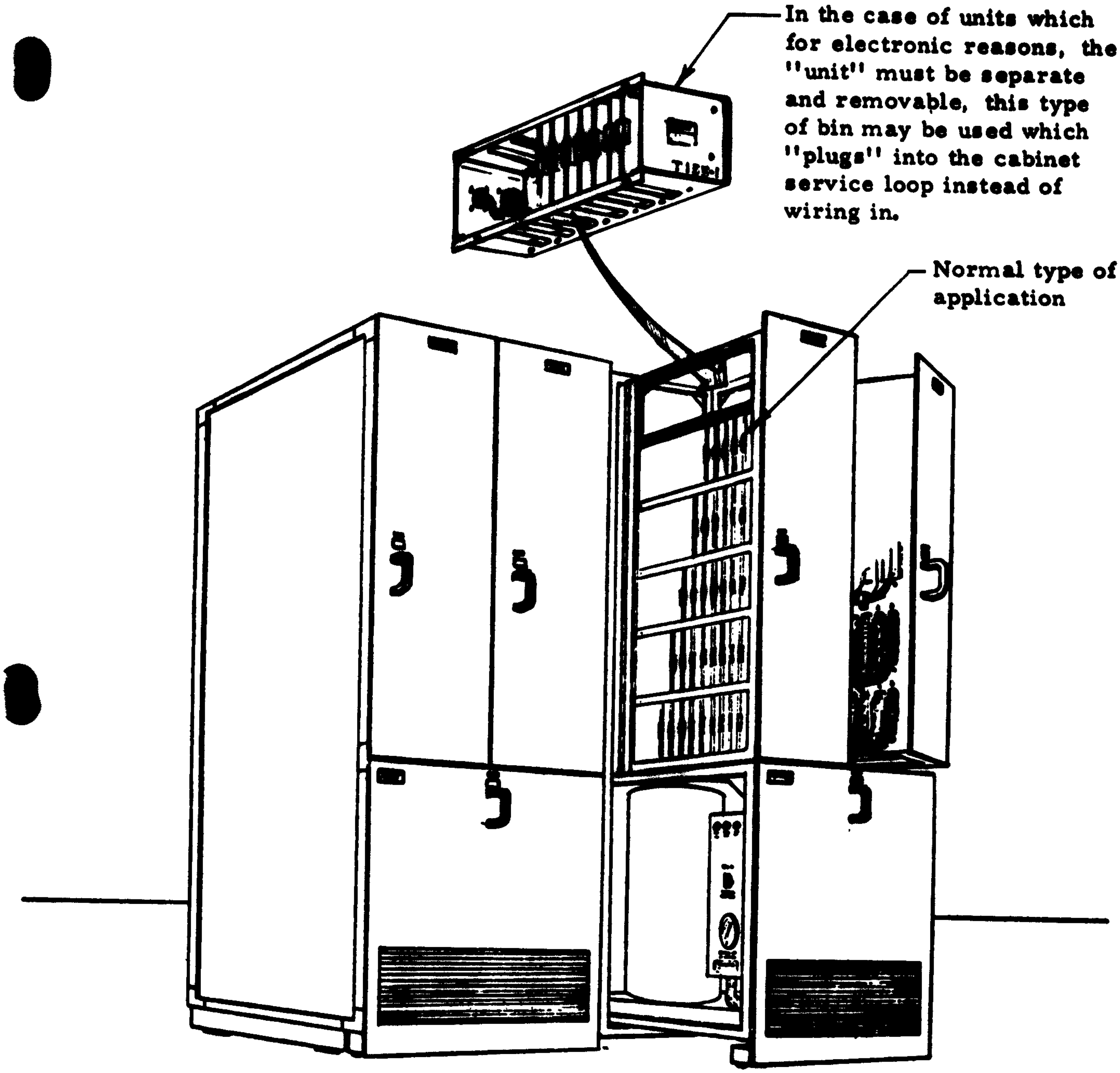


Figure 18. Recommended Modular Sub Assemblies In Pull-Out Frame

1.3 TRACKER CONTROL GROUP

1.3.1 SLEW CONTROL UNIT

1.3.1.1 DESIGN OBJECTIVES

The slew control (see figure 19) is to be used to slew trackers for the following operations:

a. Initial target acquisition

b. Manual tracking

c. Aiding of trackers which are in the automatic mode

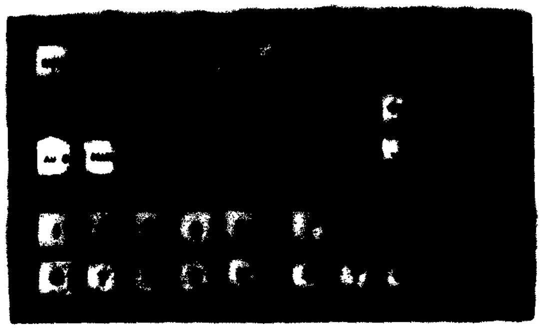
1.3.1.2 DESIGN ALTERNATIVES

1.3.1.2.1 MECHANICAL - A number of different mechanical arrangements were considered for the slewing control, such as a joy stick, a bowling ball, a pressure stick, a four-way toggle switch, a pencil and conducting surface, and a mechanical arm.

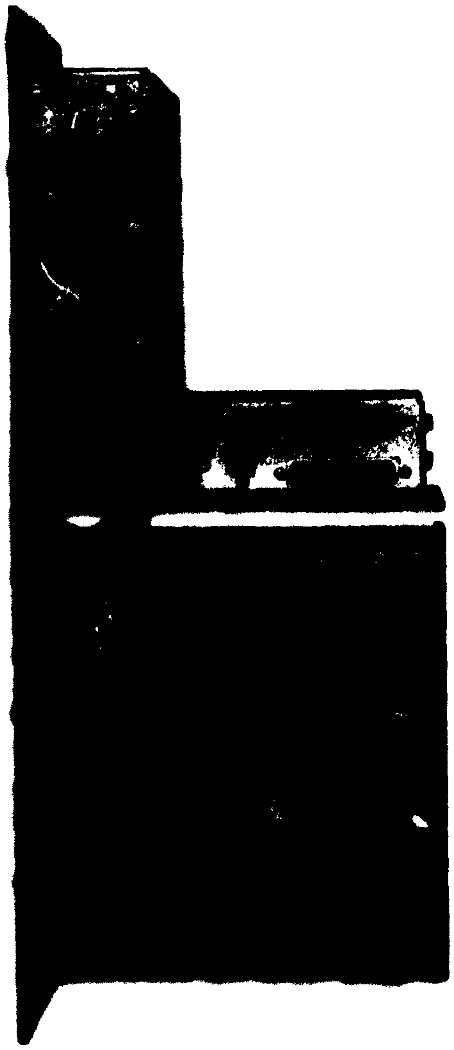
1.3.1.2.2 ELECTRICAL - A number of transducers to convert mechanical signal to electrical signal were considered. These included potentiometers, d-c tachometers and a-c tachometers for the gross motion devices, and magnetostrictive and other strain gauges for the pressure stick device.

1.3.1.3 FINAL DESIGN (see figure 20)

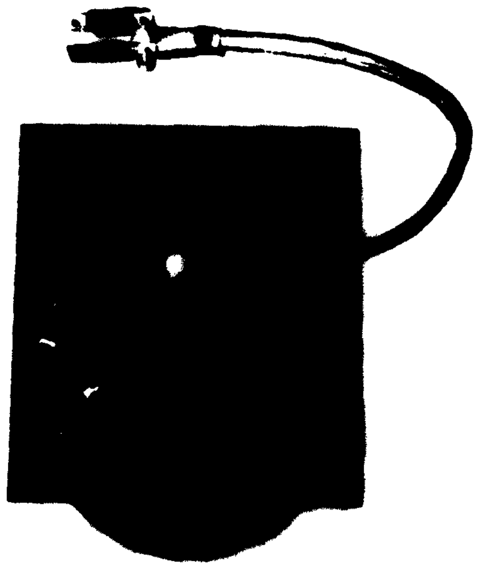
1.3.1.3.1 CHOICE OF FINAL DESIGN - After considerable study and consultation with people who had used the various devices, the gross motion joy stick was selected for the slewing control. The pressure joy stick was rejected because it lends itself only to a rate system, whereas an incremental position slewing system had been selected (refer to paragraph 1.1.1.2.2.2, Waiting Point Generator). The bowling ball was rejected because of the difficulty of building a reliable pickoff with long life expectancy and the large size of the enclosure required. The four-way toggle switch was rejected because it also lends itself only to a rate system. The pencil and conducting surface were rejected because of poor reliability associated with the conducting surface. The mechanical arm was rejected because it did not lend itself to an incremental system.



Tracker Control Panel



Tracker Control Auxiliary



Slew Control Unit

Figure 19. Tracker Control Group

A-C tachometers were chosen for the pickoff device. Although they have a quadrature signal and harmonics present at null, they have minimum friction and inertia and are relatively noise-free. D-C Tachometers were rejected because of their greater inertia, because they have brushes causing friction and wear, and because they are noisy. Potentiometers were rejected because those available were noisy or had a short life expectancy, and also to avoid possible problems in differentiation.

Because the Tracker memory is an integrator, a signal proportional to the derivative of joy-stick motion is necessary to make the motion of the tracking gate directly proportional to the joy-stick motion. The a-c tachometers conveniently provide this differentiation. They require synchronous demodulator circuits, one for each of the two channels.

1.3.1.3.1.1 MECHANICAL DESIGN

Human factor considerations place definite limitations on the external geometry of the Slew Control Unit. The need for a switch on the handle (to activate the slew control) requires that this switch be operable with a different set of muscles than those that are used to displace the entire slew stick handle; otherwise there will be an objectionable tendancy to move the stick (and, consequently, the Tracker) away from the point to which the operator has just positioned it at the time of release of the switch.

The conventional upright joystick possesses the disadvantage that the sense of lateral displacement and angular displacement are opposite for this type of application, such that when the operator displaces the stick in the direction he wishes to move the Tracker, he produces an angular motion of the stick that results in its lower end pointing away from the direction in which the Tracker moves, because the direction of movement is opposite for each side of the pivot point. The inverted joystick, with pivot point above the operator's hand, avoids this effect. Mechanically, however, the latter becomes more complex. It was judged that for this application the upright stick would not be likely to cause operator confusion because of the inversion of direction, and it was adopted accordingly.

It was requested that the slew controls be delivered with short joysticks, plus one long joystick for evaluation. A short joystick is defined as one that permits the operator to rest some portion of his hand on the stationary structure while moving the stick, and thereby to have a stationary physical reference for his control movements. In order to obtain the greatest benefit from this feature it is necessary to have the pivot point of the stick quite high, near to the point where it emerges from the surrounding structure. This is also advantageous from the standpoint of minimizing the lateral excursion of the stick at the point where it emerges from the case, thereby minimizing the lateral excursion that the dust seal must accommodate.

The hand with which the operator grasps the stick is essentially a resilient structure, having lost motion in the plane parallel to the surface of contact due to lack of rigidity in shear of the tissue between skin and bone. In view of these considerations, it becomes quite desirable that a slew stick posses a low but definite amount of inertia, insignificant starting friction, and a modest amount of resistance that increases with velocity. Otherwise, the dynamic range of the combination of operator and slew stick will suffer because of the inability of the operator to make precise adjustments directly. The characteristics of the a-c tachometer are well matched to the foregoing considerations. The mechanism for driving the tachometers was designed with minimal friction and restoring spring force accordingly. The dust cover serves also as the restoring spring for use with the short joysticks.

1.3.1.3.2 ENGINEERING CHANGES

1.3.1.3.2.1 SPACE ALLOTMENT - The space alloted for the Slew Control Unit and the Tracker Control Panel was reduced by a revision of GPL Specification 10000-523. This necessitated a mechanical redesign of the Slew Control Unit and resulted in more complicated gearing in order to package the entire Slew Control Unit, with its tachometers, in the available space. Because of the space reduction and the requirement for a rotatable joy stick, it was necessary to locate the slewing amplifier-demodulators elsewhere. The Tracker Control Auxiliary was designed and fabricated for this purpose (refer to paragraph 1.3.2).

1.3.1.3.2.2 PROVISION FOR ALIGNMENT - It was required that the Slew Control joystick contain provisions for alignment with the PPD Display, since the exact location of the joystick relative to the North axis of the display is variable. The Slew Control Unit was modified to permit alignment with the PPD Display by rotating the Slew Control Unit in its housing.

1.3.1.4 RECOMMENDATIONS

1.3.1.4.1 MECHANICAL ARRANGEMENTS - In order to optimize system performance and minimize operator fatigue, it would be desirable to engage in an experimental study using various forms of slew control. Inverted joysticks, bowling balls, pressure sticks, and others could be included in this effort, as well as the switch and its function, displacement and rate motion, etc. Such experiments can only be performed using a complete man-machine loop under conditions similar to those of actual use if conclusions obtained therefrom are to be valid.

1.3.1.4.2 **IMPROVED JOY STICK HANDLE** - The possibility of an improved joystick handle with a more positive Slew Now switch should be considered.

1.3.1.4.3 **PICKOFF DEVICES** - The size of the Slew Control Unit can be reduced and its operation improved by using 400-cps tachometers in place of the present 60-cps tachometer generators. Optical pick-off devices have low inertia, are devoid of friction and noise caused by brushes and sliders, and so could be considered for obtaining a signal suitable for differentiation.

1.3.2 TRACKER CONTROL PANEL

1.3.2.1 DESIGN OBJECTIVES

The Tracker Control Panel (see figure 19) is used by the controller in operating Trackers. The functions of the Tracker Control Panel are as follows:

a. Indicate to the controller that a Tracker has been assigned to a target by the Video Track Programmer.

b. Permit the controller to select a Tracker in order to slew it.

c. Permit the controller to slew the Tracker, either for initial acquisition or for correcting a Tracker which is tracking a target, in the normal position, fast position, or position plus velocity slew mode.

d. Indicate the status (unassigned, assigned, selected, on-target, off-target) of each Tracker assigned to a particular controller.

e. Permit selection of video input, Z gate mode, and tracking mode (automatic or coast) for each selected Tracker.

f. Permit control of the position of the 19-character display with respect to the tracking gate outline presentation on the PPD Display.

g. Permit dumping (disengaging) the selected Tracker.

h. Permit substitution of a new Tracker for a Tracker which has failed.

i. Indicate the type of video, Z gate mode, slewing mode, and the tracking mode which has been selected for the Tracker.

1.3.2.2 DESIGN ALTERNATIVES

The electrical design of the Tracker Control Panel was straightforward, as the design was dictated by the requirements of the Trackers and other equipments with which the Control Panel operates.

There was a choice of using either a rotary selector switch or eight pushbuttons for selection of the desired character offset. The pushbuttons were chosen as the most convenient for the controller.

The specification required the use of Microswitch Type 100 PB or Type 50 PB lighted pushbuttons. From a human factors standpoint, there remained minor freedom of panel layout for grouping these.

1.3.2.3 FINAL DESIGN

GPL Specification 10000-523 provided sufficient space allotment for 50 Tracker selector pushbuttons plus space for tracking mode, character block positioning, video, slew and Z gate mode selector pushbuttons.

The Honeywell 100PB type pushbutton was selected for use in the Tracker Control Panel. Although this pushbutton is relatively large, it contained highly reliable microswitches, was available with several switch arrangements which were convenient for the switching circuits of the Tracker Control Panel, contained dual lamps as a safety factor against burnout, and presented an adequate light output.

A DUMP toggle switch was incorporated in the Tracker Control Panel for the purpose of returning the Tracker to pool and erasing the associated Tracker data after completion of the tracking assignment.

A SUBS (substitute) pushbutton was incorporated in order to permit replacement of a failing Tracker.

Six VIDEO selector pushbuttons were incorporated in order to select the desired video input to the Tracker and to indicate the type video which has been selected.

Two Z Gate pushbuttons were incorporated in order to control Z gate mode and to indicate the selected Z gate.

Two pushbuttons were incorporated to select the desired tracking mode (automatic or coast) and to indicate the tracking mode which has been selected.

Eight pushbuttons were incorporated to select character block offset.

Because of the decision to use an incremental type of slew control, it was decided to employ two position slewing modes, normal and fast. A position plus velocity (rate-aided) slewing mode was also provided. Three pushbuttons were incorporated on the Tracker Control Panel for selection of the slewing mode. The normal Position slew mode and the Position plus Velocity slew mode pushbuttons also indicate the slewing mode which has already been selected.

The slewing mode is selected for a Tracker Control Panel rather than for a Tracker. Automatic selection of the position slewing mode is accomplished when a new Tracker is selected at a waiting point. Automatic selection of the Position plus Velocity slew mode is accomplished when a Tracker is selected after it has been tracking. The Fast Slew pushbutton is of the instantaneous return type and must be depressed during the entire time that the fast slew mode is employed.

Prior to fabrication of the Tracker Control Unit, the front panel design was submitted to GPL for human engineering evaluation by the FAA.

1.3.2.3.1 ENGINEERING PROBLEMS

Flicker of Tracker Control Panel indicator lamps constituted a major engineering problem. The design of the original timing sequence resulted in the lamps being pulsed at a rate of 30 cps, which caused an objectionable flicker. The frequency of the time-sharing sequence was therefore doubled. The 60-cps rate was accomplished by overlaping logic timing of the Normal Console Gate and Delayed Console Gate signals.

1.3.2.3.2 ENGINEERING CHANGES

Revision of GPL Specification 10000-523 resulted in the reduction of the space allotment for the Tracker Control Panel by a factor of 2/3. In order to fulfill the required functions of Tracker selection and control with space allowed, the technique of using local Tracker numbers was adopted. By this method, only twenty Tracker selector pushbuttons are required.

The reduction of space prevented the inclusion of Tracker control, slewing and status indication circuits within the Tracker Control Panel assembly. A separate assembly, the Tracker Control Auxiliary, was therefore provided to house these circuits as well as the slew amplifiers-demodulators (See 1.3.2.2.3).

Accordingly, the Tracker Control Panel was redesigned in compliance with the revised specification. The 100 PB pushbuttons were retained for the function of selecting Trackers and indicating Tracker status, as the dual lamps and optical efficiency were felt to be important to that function. Other functions requiring lighted pushbuttons without multiple status indication were changed to type 50 PB units. Functions that did not require lighting at all were changed to other types of non-illuminated switches. The FAST SLEW, POS (position) SLEW, POS + VEL (rate-aided slew), VIDEO and Offset Selector switches were mounted in single clusters that could be located and operated entirely by feel. The cluster of Offset Selector switches was designed so that on initial installation, the direction of each offset button can be made to correspond with the orientation of the operator position with respect to the PPD Display.

Prior to fabrication of the newly designed Tracker Control Panel, the control panel design was submitted to GPL for approval. The TIC control panel layout was rejected and a new layout was devised by GPL, specifying the use of Honeywell 50 PB pushbuttons. These pushbuttons were considered by TIC to be inferior to the 100 PB units in respect to mechanical construction, switch arrangements, and optical properties, and they have only one bulb. The Honeywell 50 PB pushbuttons, however, were used on GPL's instructions. This has necessitated boring out of the Tracker Select pushbuttons in order to permit more light to emerge from the center of the button to enable the observer to distinguish three light levels (bright, dim, off).

1.3.2.4 RECOMMENDATIONS

1.3.2.4.1 **PUSHBUTTONS** - A better pushbutton should be selected for use on the panel, preferably a button with two lamps to minimize bulb failures. A new button should also be selected for better optics to obtain brighter indications.

1.3.2.4.2 **FEWER PUSHBUTTONS** - In order to accommodate larger push-buttons, it may be necessary to use fewer buttons on the panel. This can possibly be accomplished by reducing the number of video pushbuttons. It is unlikely that any one controller will control as many as twenty Trackers, and, if this is definitely determined, the number of Tracker Selector pushbuttons should be reduced accordingly.

1.3.2.4.3 **HUMAN FACTORS** - When the Tracker Control Panels are in use in a complete man-machine system it is recommended that a review of the design be made from a human factors standpoint.

1.3.3 TRACKER CONTROL AUXILIARY

1.3.3.1 **DESIGN OBJECTIVES** - The Tracker Control Auxiliary was needed to house the amplifiers and demodulators necessary for utilizing the output of the Slew Control Unit and to house the drivers for the lamps on the Tracker Control Panel. The Tracker Control Auxiliary also contains the necessary logic and gating circuits for the above functions.

1.3.3.2 **DESIGN ALTERNATIVES** - The electrical design was substantially dictated by the requirements of the associated Tracker control circuits. Design alternatives were accorded only limited consideration, such as a review of the properties of various demodulator circuits.

1.3.3.3 **FINAL DESIGN** (see figure 20) - The demodulators are required to accept the 60-cps output from the tachometer generators. The output of the demodulators is used in a 60-cps time-shared system. The use of long time-constant filters is clearly prohibited because the introduction of an excessive lag between slew stick displacement and visual presentation would be highly annoying to the operator and would require much more concentration for the slewing operation.

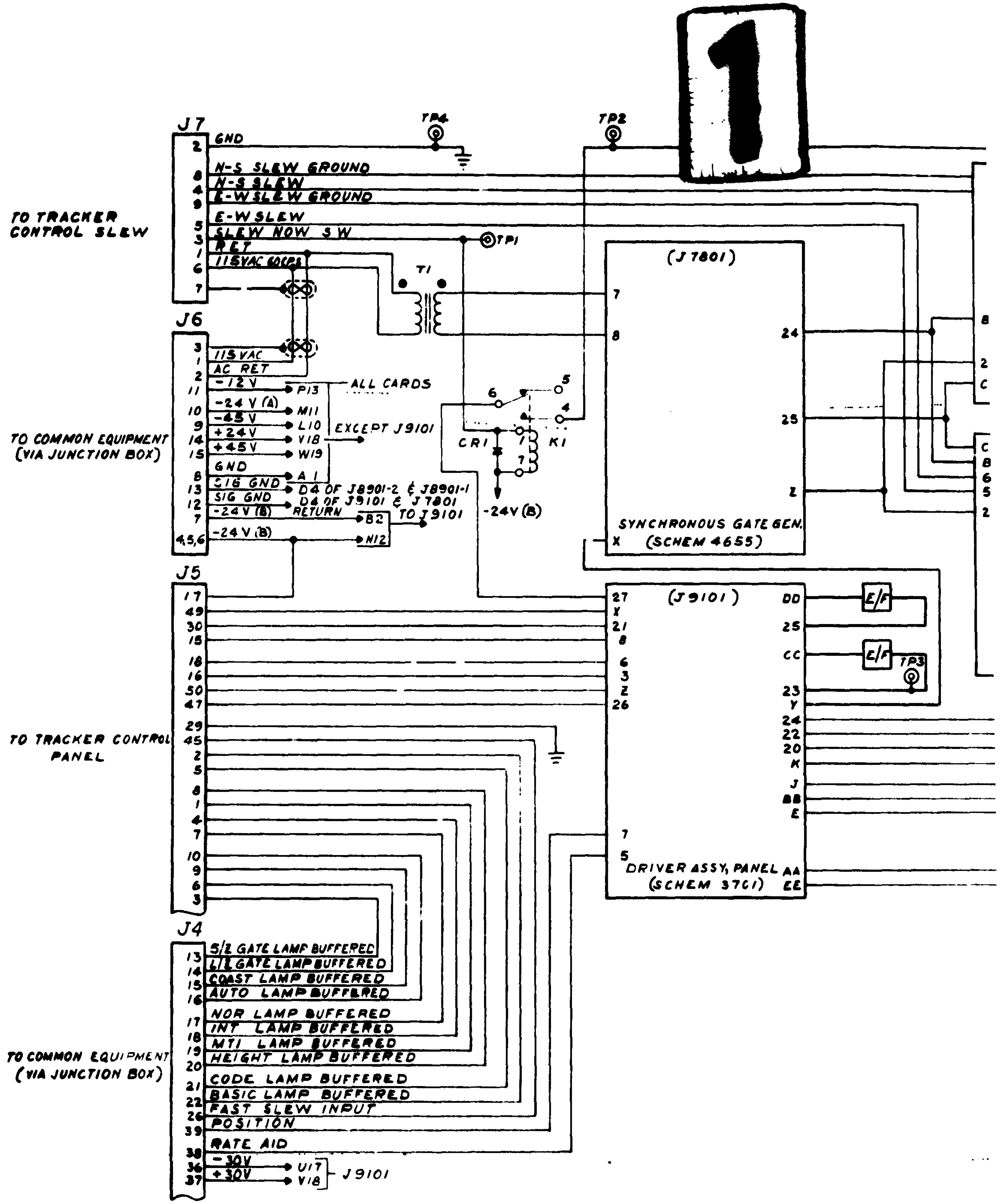
The design approach selected involves sampling the output voltage of the tachometer generator once per cycle when it is at a maximum and then clamping and holding this voltage until another sample is taken during the same portion of the next cycle. The voltage thus stored is updated on each cycle and may be read out by the time-shared system as required. This approach proved satisfactory and no problems were encountered.

1.3.3.3.1 ENGINEERING CHANGES

It was originally intended to construct the demodulators so as to obtain a maximum output of plus or minus 20 volts. Changing this to plus or minus 10 volts permitted the use of relatively inexpensive germanium transistors and resulted in a significant cost savings.

The first installation outline submitted to GPL used standard TIC chassis components. It was planned to install this in the console. This outline was rejected, with instructions to design the unit to fit in unused space in a pylon built by Link Inc., which is associated with the same console. This necessitated the design of an entirely new chassis and non-standard cards to fit the space allotted.

1.3.3.4 **RECOMMENDATIONS** - No indication of a requirement for redesign has been observed to date.


1
J7
GND
TP4
TP2
N-S SLEW GROUND
N-S SLEW
E-W SLEW GROUND
E-W SLEW
SLEW NOW SW
RET
115VAC 60CPS
TP1
TO TRACKER CONTROL SLEW
T1
(J7801)
SYNCHRONOUS GATE GEN.
(SCHEM 4655)
J6
115VAC
AC RET
-12V
P13
ALL CARDS
-24 V (A)
M11
-45V
L10
+24V
V18
EXCEPT J9101
+45V
W19
GND
A1
SIG GND
D4 OF J8901-2 & J8901-1
SIG GND
D4 OF J9101 & J7801
-24V (B)
RETURN
B2
TO J9101
-24 V (B)
H12
TO COMMON EQUIPMENT
(VIA JUNCTION BOX)
CR1
K1
-24V (B)
J5
(J9101)
E/F
TP3
TO TRACKER CONTROL PANEL
DRIVER ASSY, PANEL
(SCHEM 3761)
J4
S/Z GATE LAMP BUFFERED
L/Z GATE LAMP BUFFERED
COAST LAMP BUFFERED
AUTO LAMP BUFFERED
NOR LAMP BUFFERED
INT LAMP BUFFERED
MTI LAMP BUFFERED
HEIGHT LAMP BUFFERED
CODE LAMP BUFFERED
BASIC LAMP BUFFERED
FAST SLEW INPUT
POSITION
RATE AID
-30V
+30V
U17
V18
J9101
TO COMMON EQUIPMENT
(VIA JUNCTION BOX)

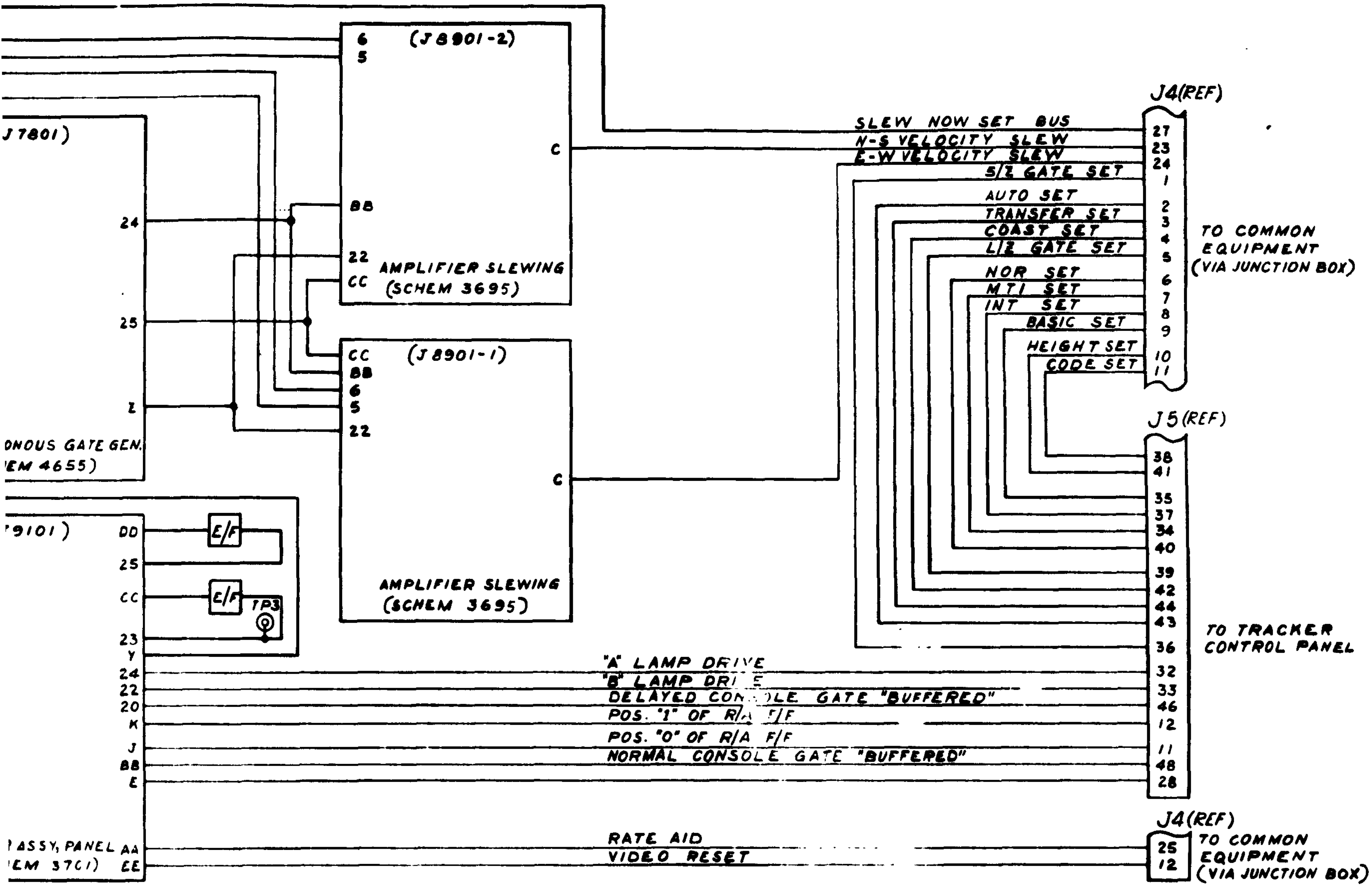


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Figure 20. Tracker Control Auxiliary, Block Diagram

1.4 VIDEO TRACK PROGRAMMER

1.4.1 DESIGN OBJECTIVES

1.4.1.1 FUNCTIONS - The Video Track Programmer (VTP) must perform the following operations:

a. Select and control Video Trackers.

b. Furnish data for display on the PPDD consoles.

c. Furnish data for control of the Local and PAR Approach Display indicators.

d. Furnish data for Beacon Decoder operation.

1.4.1.2 DATA SOURCES - The primary source of data for the VTP is the Transition Data Processing Group. TIC Drawing No. 4572 shows the messages which are sent to the VTP and the message formats. In addition, data and/or control signals are obtained from the Tracker Control Panels and from the Local Approach Display pushbuttons.

1.4.1.3 TRACKER CALL UP - Upon receipt of a tracker call-up message, the VTP must select a Tracker from the designated pool, assign this Tracker to the Tracker Control Panel of the operator who originated the request, and store the data in the correct drum location for presentation on the PPD Display during the regular print up. The VTP must be capable of fulfilling this function for one pool of 50 Trackers or two pools of 25 Trackers each, and to as many as ten Tracker Control Panels. When a Tracker is assigned to a control panel, the operator at the control panel must be able to perform all the operations required in order to control the Tracker.

1.4.1.4 DATA TO BE STORED - The Video Track Programmer must store and supply to the Character Generator for use by PPD Displays at the appropriate time, the following data:

a. 50 19-character video Tracker formats

b. 50 circles associated with Video Trackers

c. 30 19-character waiting-point formats

d. 1 112-character return-to-base corridor display

e. 1 64-character scramble-corridor display

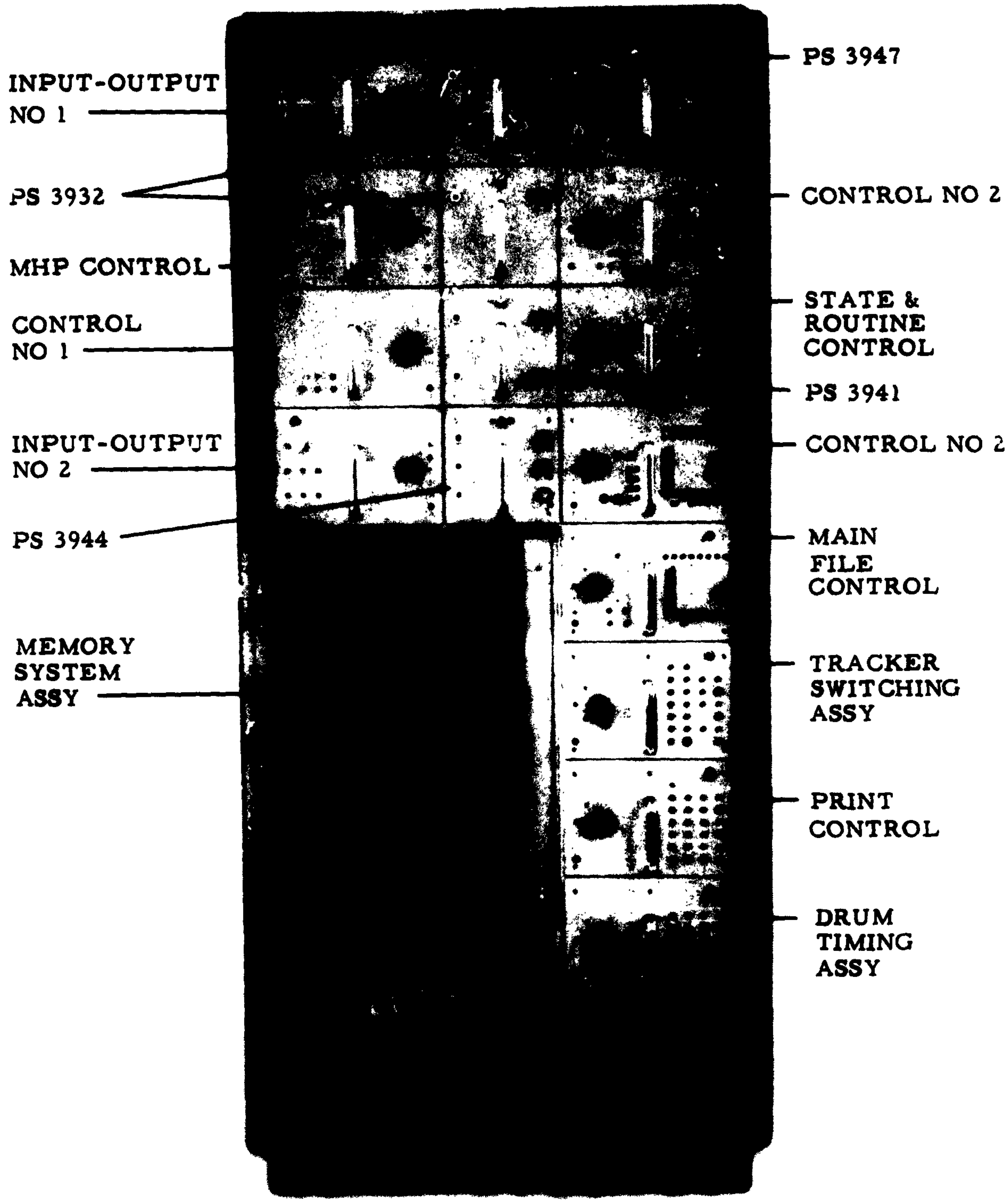


Figure 21. Video Track Programmer

f. 5 30-character landing-sequence displays

g. 1 94-character missed-approach display

h. 5 missed-approach route schedule position crosses and LS numbers.

The data required to provide these displays is obtained in the form of messages from the TDPG (Transition Data Processing Group).

1.4.1.5 DATA PROCESSING - The Video Track Programmer must process the data required to control the Local and PAR Approach Displays and generate the timing and control signals required by the Approach Display Processor. This data is received in the form of a message from the TDPG and from the control buttons on the Local Approach Display.

Upon receiving a beacon code assignment message or upon substituting Trackers, the Video Track Programmer must supply control signals and data to allow the beacon decoders to function properly.

1.4.1.6 VIDEO TRACK PROGRAMMER, TYPE II - After the logical design of the Type II programmer was nearly completed, GPL Specification 10000-523 was revised and the requirement for the Type II programmer was deleted. The Video Track Programmer Type II was intended to transfer data and supply the necessary control signals to cause the Analog Computer (Terminal Area Computer), which was also cancelled, to perform its functions. These functions included computation of error in time to fly, computation of time to fly, and computation of missed-approach data. The data required by the Analog Computer to perform these functions were:

1. Estimated time of landing
2. Routes
3. Profiles (TAS versus altitude characteristics)

1.4.1.7 POWER SUPPLIES - The original load requirements for the Video Track Programmer power supplies were as follows:

Volts DC	*Regulation	Ripple	Load (ma)
-24.0	3.0%	0.1%	1000
-18.0	3.0%	0.1%	2000
**-15.0	3.0%	0.1%	5000
-12.0	3.0%	0.1%	2000

**-7.0	3.0%	0.1%	4000
-1.5	3.0%	0.1%	1000
+1.5	3.0%	0.1%	1000
**+1.5	3.0%	0.1%	2000
3.0	3.0%	0.1%	1000
+18.0	3.0%	0.1%	2000

* No load to full load and ±10% of nominal input
** Required for the Memory Drum Subsystem

Design objectives given for the Conditioner-Generator Unit power supplies in paragraph 1.1.6.1.2 also apply to the Video Track Programmer power supplies.

1.4.1.8 CABINET - Design objectives for the Video Track Programmer cabinet were the same as the objectives for the Conditioner-Generator Unit cabinet (paragraph 1.1.7.1).

1.4.2 DESIGN ALTERNATIVES

Two major elements of the VTP presented possible alternatives at the beginning of the design:

1. The storage media
2. The programming technique

1.4.2.1 STORAGE - The alternative storage media which might have been used were tape and ferrite cores. Tape was ascertained to have lower reliability and to present speed problems, and was therefore rejected. Core memories were determined to be unjustified economically.

1.4.2.2 PROGRAMMING - The alternative programming technique which was considered was a stored program. It was decided that a stored program would unduly increase the required storage capacity and would reduce the speed of operation of the VTP. Therefore, stored programming was rejected as a programming technique. The final design used drum storage and fixed-wired programs.

1.4.2.3 DRUM TIMING CIRCUITS - An alternate method which might have been used to generate some of the drum timing signals would have utilized permanently recorded signals of the required nature on tracks of the storage drum. The

increased storage required, the costs involved, and the reduced flexibility, in light of the varying requirements, led to the rejection of that method.

1. 4. 2. 4 STATE AND ROUTINE CONTROL - These functions can be performed by storing the various control commands on the storage drum. The increased storage requirements and the increased time required for access to the commands, which would have resulted in slower overall operation of the VTP functions, caused rejection of stored programming as a control technique.

An alternative was to control the VTP by means of fixed-wire programming. This is the method which was selected.

1. 4. 2. 5 POWER SUPPLIES - Magnetic, transistor and vacuum tube regulated power supplies were considered. Other alternatives were the same as those of the Conditioner-Generator Unit power supplies (paragraph 1. 1. 6. 2).

1. 4. 2. 6 CABINET - The design alternatives were basically the same as for the Conditioner-Generator Unit (paragraph 1. 1. 7. 2).

1. 4. 3 FINAL DESIGN (see figures 22 and 23)

1. 4. 3. 1 GENERAL - After the basic decisions as to the elements to be used in fabricating the Video Track Programmer were made, (drum storage, wired program, and diode-transistor logic), the task of designing the Video Track Programmer became a problem of formulating the description of a system which would perform all those functions required of the VTP and of reducing this description to appropriate logical equations. These equations then were processed to obtain schematic lists of the wiring required to implement the equations in the finished equipment. These lists differ from the usual wire lists in that they call out specific connections to logic circuit components. To formulate the description of the system, a tabulation was made of the steps necessary to carry out each of the required operations. Then each major step of each operation was described in detail. Figure 22 illustrates the results of this process.

In formulating the routine structure, minimization of hardware by time-sharing was practiced to the greatest degree practicable. Consideration of the requirements for simplicity of routine structure in order to provide optimum maintainability conflicted with this aim, so that the final design is the result of compromises between these goals. Wherever possible, logical elements used to implement a particular function were consolidated into a single package. Due to space limitation, this attempt was not completely successful. Thus, Input-Output Assembly No. 2 contains elements of the print cycle logic (the rest of the logic

being in the Print Control assembly) and also contains elements of the TDPG data communication logic. The rest of this logic is contained in Input-Output Assembly No. 1 and in the MHP (military high performance) Control Assembly. Other functional logic assemblies are the timing logic in the Drum Timing Assembly, the tracker control logic in the Tracker Switching Assembly, state generation logic in the State and Routine Control Assembly, and main file data processing logic in the Main File Control Assembly. Three other chassis provide the other miscellaneous logical elements to perform the other functions required of the VTP.

1.4.3.2 PROGRAM - The program of the VTP consists of:

a. 13 routines initiated by messages from the TDPG

b. 3 routines initiated from the Tracker Control Panel

c. The print cycle routine initiated within the VTP itself

d. 15 test routines

e. The independent tracker control and input-output routines

The implementation and control of these routines is performed by flip-flops and storage registers as listed in TIC Drawing 6034. In addition, there are six recirculating registers on the magnetic drum. Three of these registers are 1/10 of a drum revolution in length (30 characters), two registers are 1/50 of a drum revolution in length (6 characters), and one register is 1/5 of a drum revolution in length (60 characters). The 30-character registers are used for storing, input data, for general data storage, and for main-file operations. The 6-character registers are used for index operations. The 60-character register is used processing long messages and for special operations involved in the "No Tracker" print cycle operation for circle printing.

The specific operation being performed by the VTP at any given time is determined by a cyclic routine search. In this search the print cycle is given priority over all other operations. Other routines were assigned priorities in the following order:

a. Print cycle

b. Routines initiated by Tracker Control Panel commands

c. Routines initiated by message from the Transition Data Processing Group

d. Routines initiated by commands from the Local Approach Display panel.

1.4.3.3 MAGNETIC DRUM ASSEMBLY - The VTP magnetic drum is required to store the data associated with 50 trackers, special displays, and the

auxiliary storage required to process the data. The storage device had to be highly reliable, available in a reasonable time, and available at a reasonable cost. Var. .us storage alternatives were mentioned in paragraph 1. 4. 2. 1 above.

The delivery schedule dictated that the GPL recommendation to employ Aeronutronics Systems Incorporated to design and produce the drum subsystems be accepted. After the subcontract had been let to the vendor, it was necessary to reorganize the drum to facilitate the changes mentioned in paragraph 1. 4. 8. 12. This caused some delay in delivery of the drum subsystem and some increase in costs. The schedule required that the use of existing Aeronutronics designs which had several shortcomings as follows.

a. Power supplies were different from those used throughout the rest of the VTP.

b. Some obsolete transistors were employed

c. Level shifters were required to translate the VTP logic levels to those used inside the drum subsystem.

d. The read amplifiers supplied Manchester waveforms rather than NRZ waveforms as are used throughout the VTP.

Notwithstanding these shortcomings, the drum subassembly produced by Aeronutronics has proven to be a satisfactory solution to the storage requirements of the VTP.

1. 4. 3. 4 DRUM TIMING CIRCUITS - The function to be performed by the drum timing assembly is the generation of those timing signals required to address, control, and otherwise properly utilize the capabilities of the drum storage device.

A series of counters, with the necessary logic to generate the required timing and control functions, was selected as the most appropriate method of performing the control functions.

1. 4. 3. 5 INPUTS AND OUTPUTS TO TDPG - The functions required for communication with the Air Traffic Control Data Processor are performed by circuits primarily occupying Input-Output Assembly No. 1, the MHP Control Assembly, and part of Input-Output Assembly No. 2. Minor elements are located in other chassis. Various control signals, data processing control elements, and required buffers, drivers, and logic circuits are necessary to perform these functions, which include accepting long and short messages, detecting parity errors, controlling message acceptance, recognizing and reacting to the end of the message, and preparation and transmission of messages pertaining to Tracker assignments and to control of the Approach Display.

1.4.3.6 CONTROL OF CHARACTER GENERATOR - Control of the print cycle is accomplished by logic circuits, buffers, and drivers primarily occupying the Print Control Assembly and part of the Input-Output Assembly No. 2. These circuits supply the message data and the control signals required to enable the Character Generator to present the tracker character formats, fix-point character formats, landing sequence situation displays, missed-approach display, return-to-base display, scramble-corridor display, cross displays for missed approach, and schedule-circle displays to the appropriate controllers.

1.4.3.7 TRACKER SWITCHING ASSEMBLY - The Tracker Switching Assembly contains most of those buffers, drivers and logic elements required to enable the Tracker Control Panels to control the pool of Trackers. This function includes the ability to slew, dump, or substitute Trackers, to control the operating state of the selected Tracker, to select the video to be utilized by the Tracker, and to change the offset of the character format associated with the Tracker.

1.4.3.8 STATE AND ROUTINE ASSEMBLY - In performing its function, it is necessary that the VTP progress through the various states of specific routines by orders from the TDPG, Tracker Control Panel, Approach Display, or the print-cycle timer. The buffers, drivers, and logic elements which control this progress are primarily those located in the State and Routine Assembly and also Control Assembly No. 1.

The technique selected was to control the VTP by means of registers called the state (KY) counter and routine (KZ) register interconnected by fixed-wire logic so as to perform the functions required.

1.4.3.9 MAIN FILE CONTROL ASSEMBLY - To control the processing of the data contained in the main file of the drum is the function of logic elements located primarily in the Main File Control Assembly. The data contained in this main file is the primary data for generation of the Tracker character format displays.

1.4.3.10 GENERAL CONTROL ASSEMBLIES - Control Assemblies No. 1, 2, and 3 contain the buffers, drivers, and logic elements required to supplement the units mentioned previously and to perform the miscellaneous logic functions not previously described but required to permit the VTP to perform its function.

1.4.3.11 POWER SUPPLIES - Transistorized power supplies were selected for the reasons given in paragraph 1.1.6.3.1.

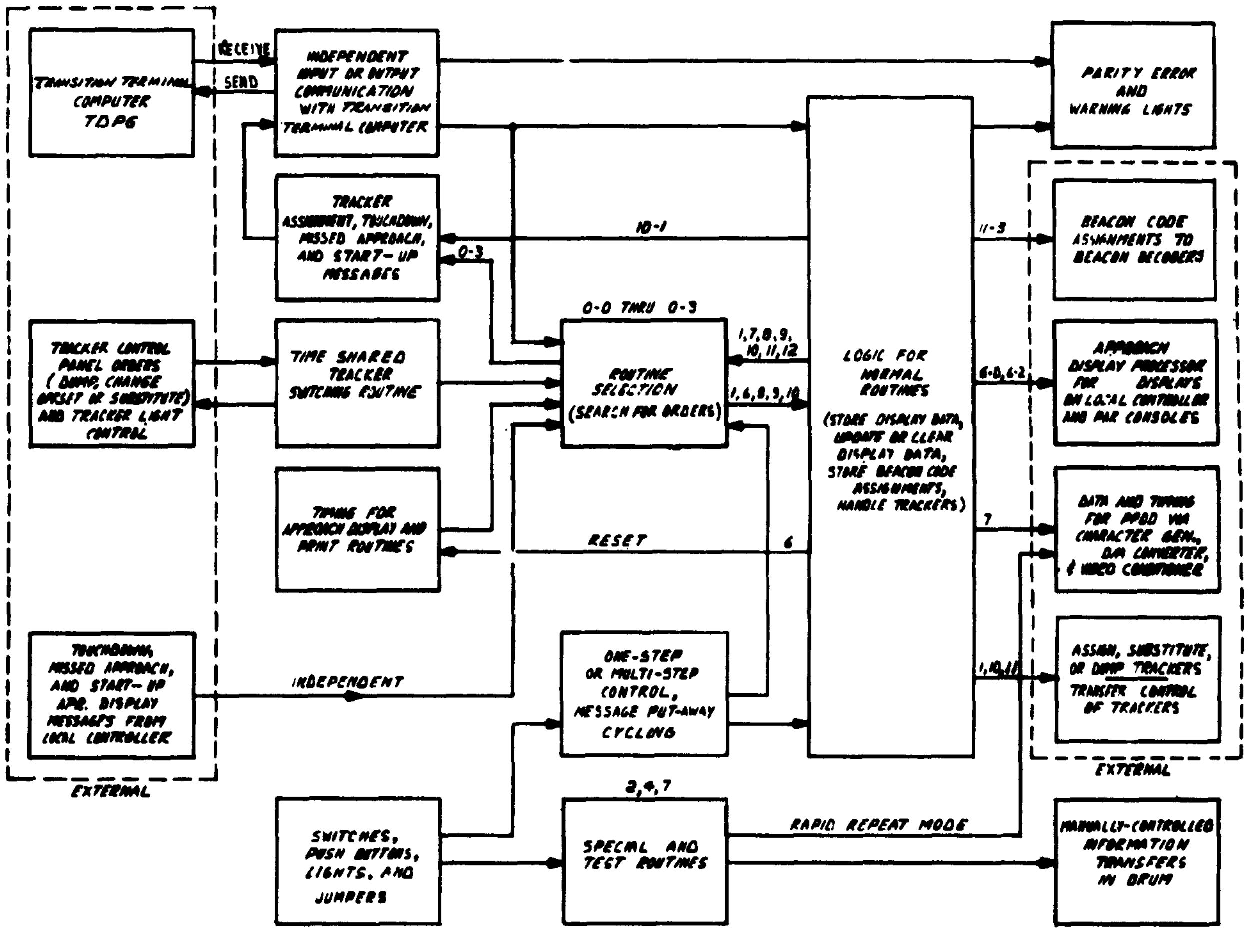
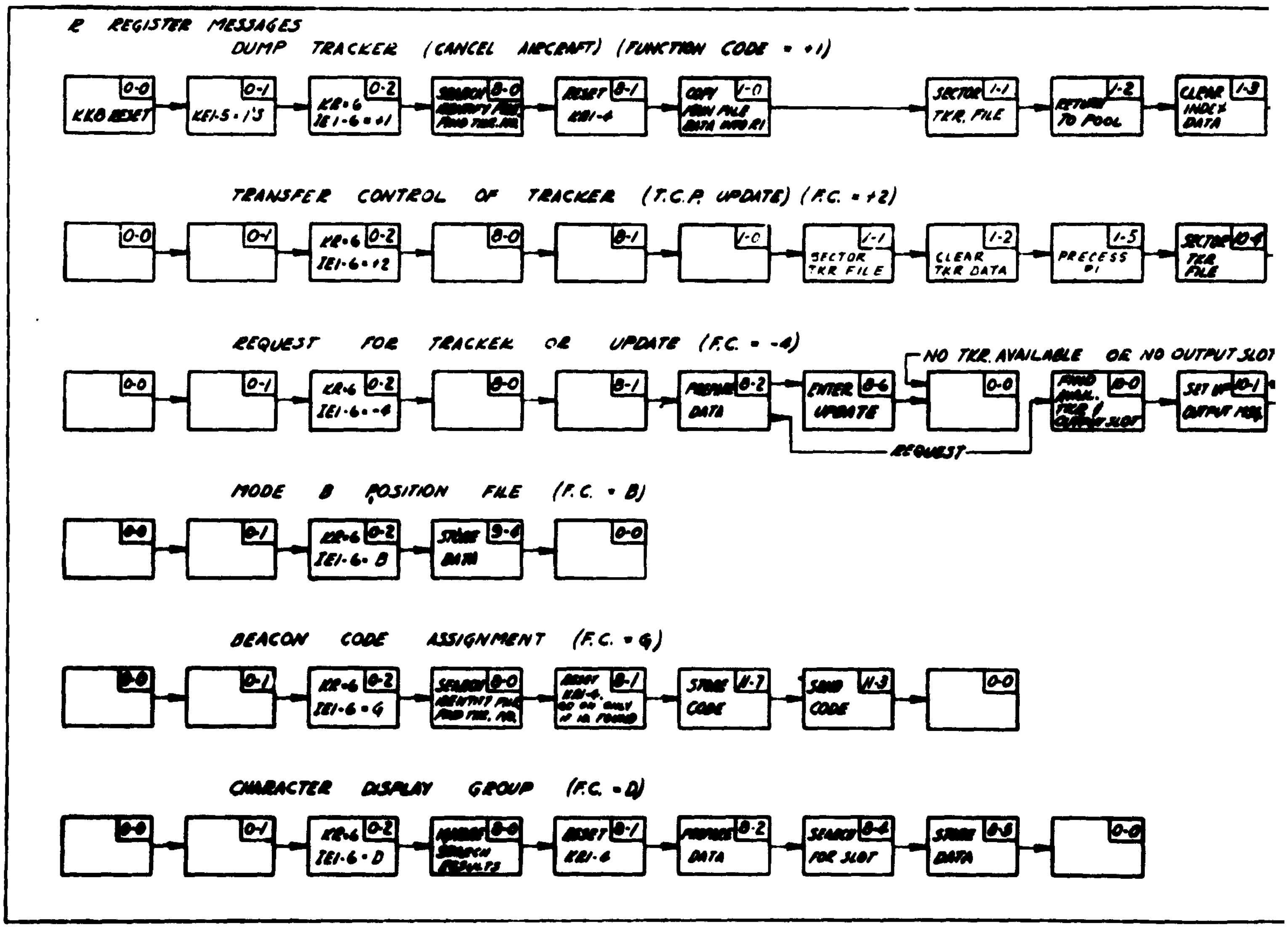


Figure 22. Video Track Programmer, Block Diagram

1


R REGISTER MESSAGES
DUMP TRACKER (CANCEL AIRCRAFT) (FUNCTION CODE = +1)
0-0 KKB RESET
0-1 KEI-5 = 1'S
0-2 KR = 6 IE 1-6 = +1
8-0 SEARCH IDENTITY FILE FIND TRK. NO.
8-1 RESET KBI-4
1-0 COPY FROM FILE DATA INTO RI
1-1 SECTOR TKR. FILE
1-2 RETURN TO POOL
1-3 CLEAR INDEX DATA
TRANSFER CONTROL OF TRACKER (T.C.P. UPDATE) (F.C. = +2)
0-0
0-1
0-2 KR = 6 IEI-6 = +2
8-0
8-1
1-0
1-1 SECTOR TKR FILE
1-2 CLEAR TKR DATA
1-5 PRECESS PI
10-4 SECTOR TKR FILE
REQUEST FOR TRACKER OR UPDATE (F.C. = -4)
0-0
0-1
0-2 KR = 6 IEI-6 = -4
8-0
8-1
8-2 PREPARE DATA
8-6 ENTER UPDATE
NO TKR. AVAILABLE OR NO OUTPUT SLOT
0-0
10-0 FIND AVAIL. TKR & OUTPUT SLOT
10-1 SET UP OUTPUT MSG.
REQUEST
MODE B POSITION FILE (F.C. = B)
0-0
0-1
0-2 KR = 6 IEI-6 = B
9-6 STORE DATA
0-0
BEACON CODE ASSIGNMENT (F.C. = G)
0-0
0-1
0-2 KR = 6 IEI-6 = G
8-0 SEARCH IDENTITY FILE FIND TRK. NO.
8-1 RESET KBI-4, GO ON ONLY IF NO. FOUND
11-7 STORE CODE
11-3 SEND CODE
0-0
CHARACTER DISPLAY GROUP (F.C. = D)
0-0
0-1
0-2 KR = 6 IEI-6 = D
8-0 SEARCH RESULTS
8-1 RESET KBI-4
8-2 PREPARE DATA
8-4 SEARCH FOR SLOT
8-5 STORE DATA
0-0

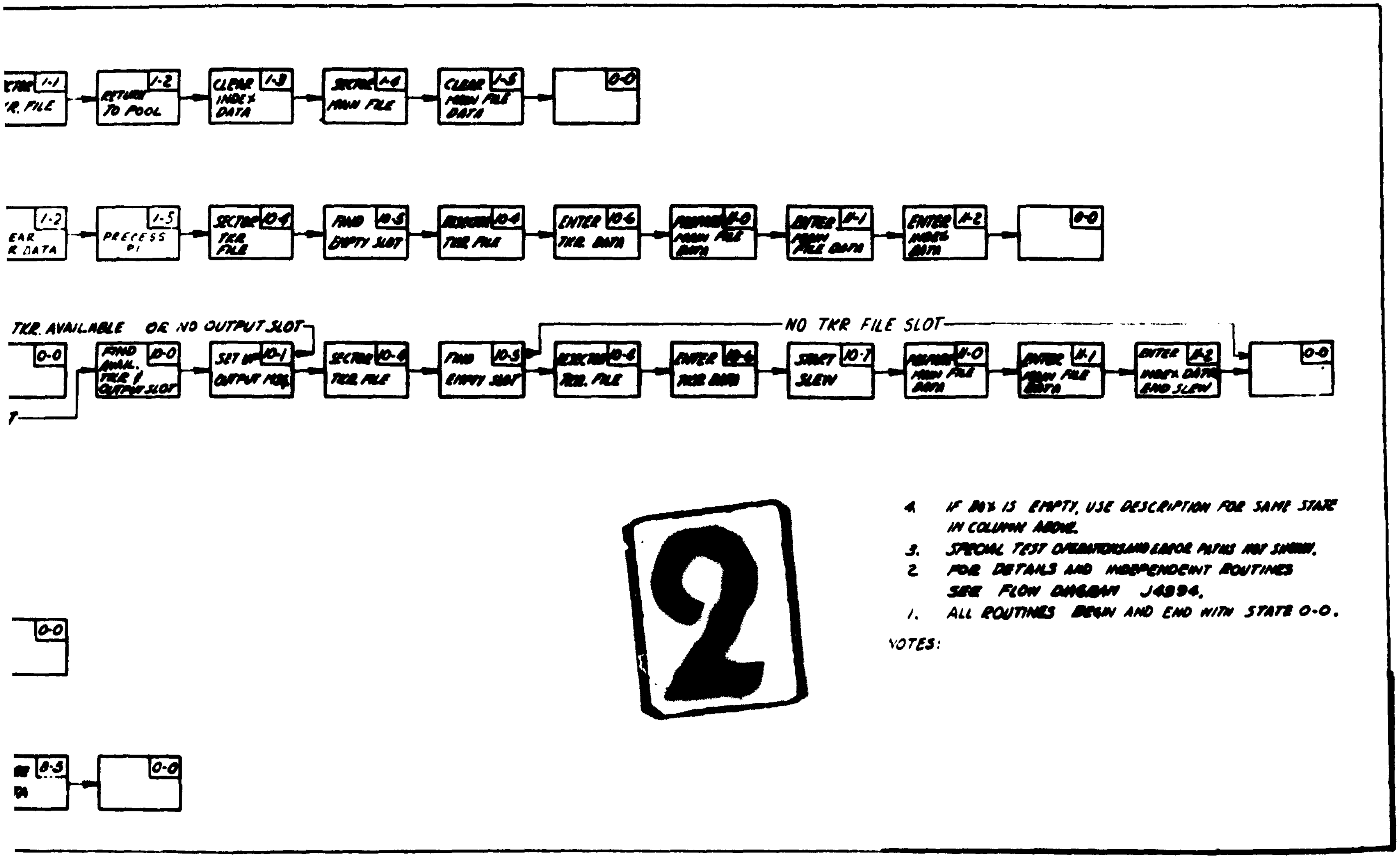
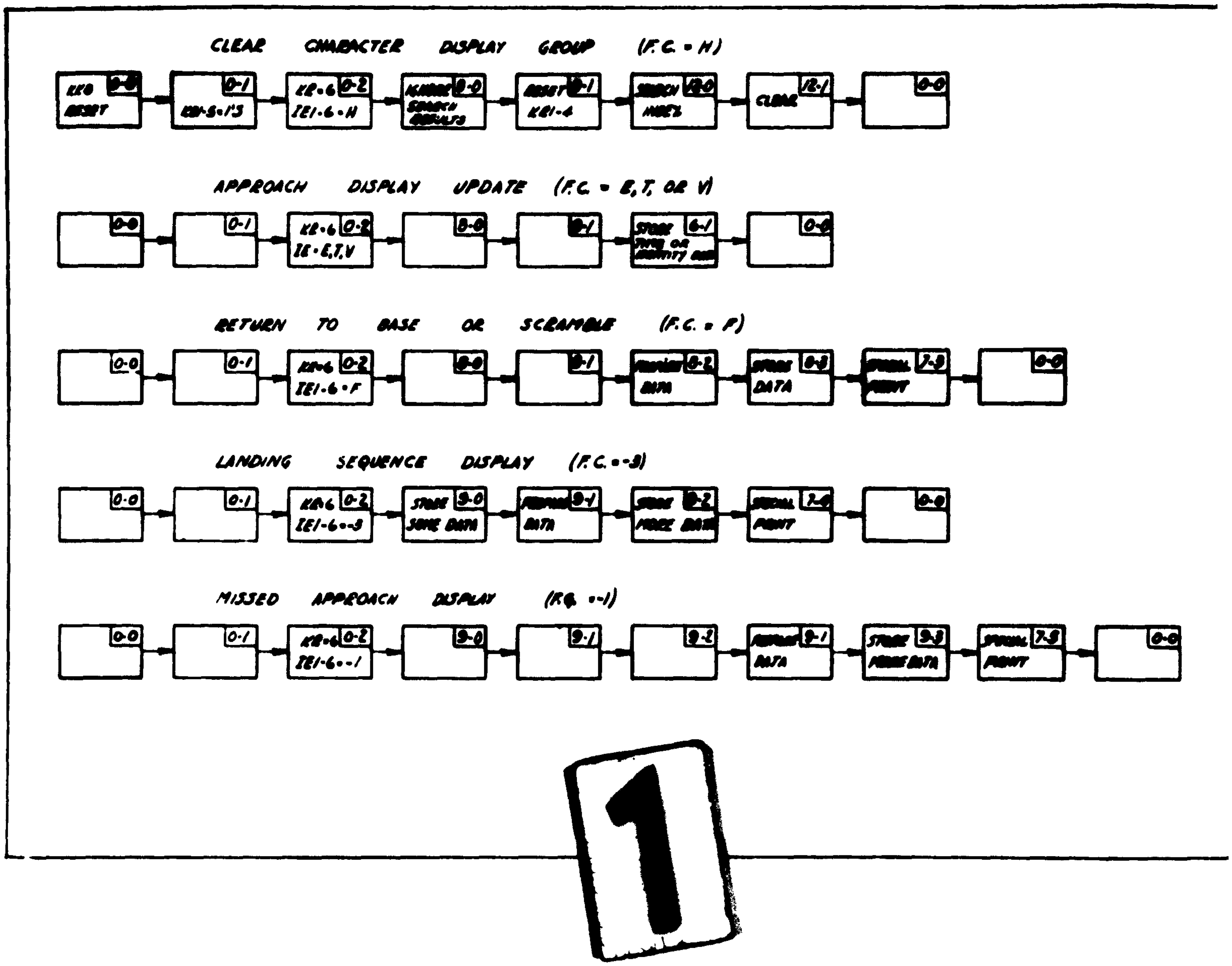


Figure 23. Video Track Programmer, Functional Flow Diagram

Sheet 1 of 3



CLEAR CHARACTER DISPLAY GROUP (F.C. = H)
APPROACH DISPLAY UPDATE (F.C. = E, T, OR V)
RETURN TO BASE OR SCRAMBLE (F.C. = F)
LANDING SEQUENCE DISPLAY (F.C. = -3)
MISSED APPROACH DISPLAY (F.C. = -1)

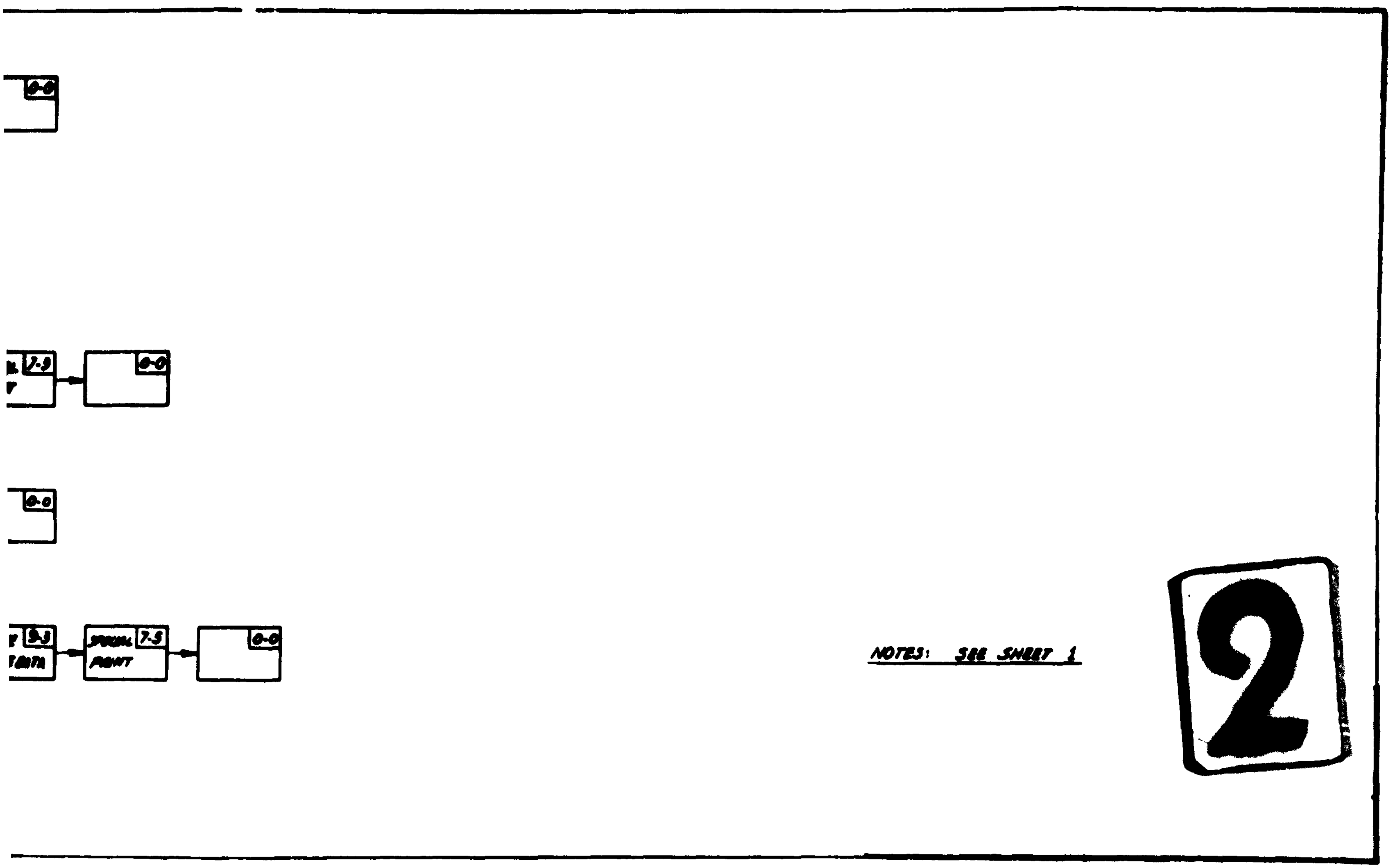
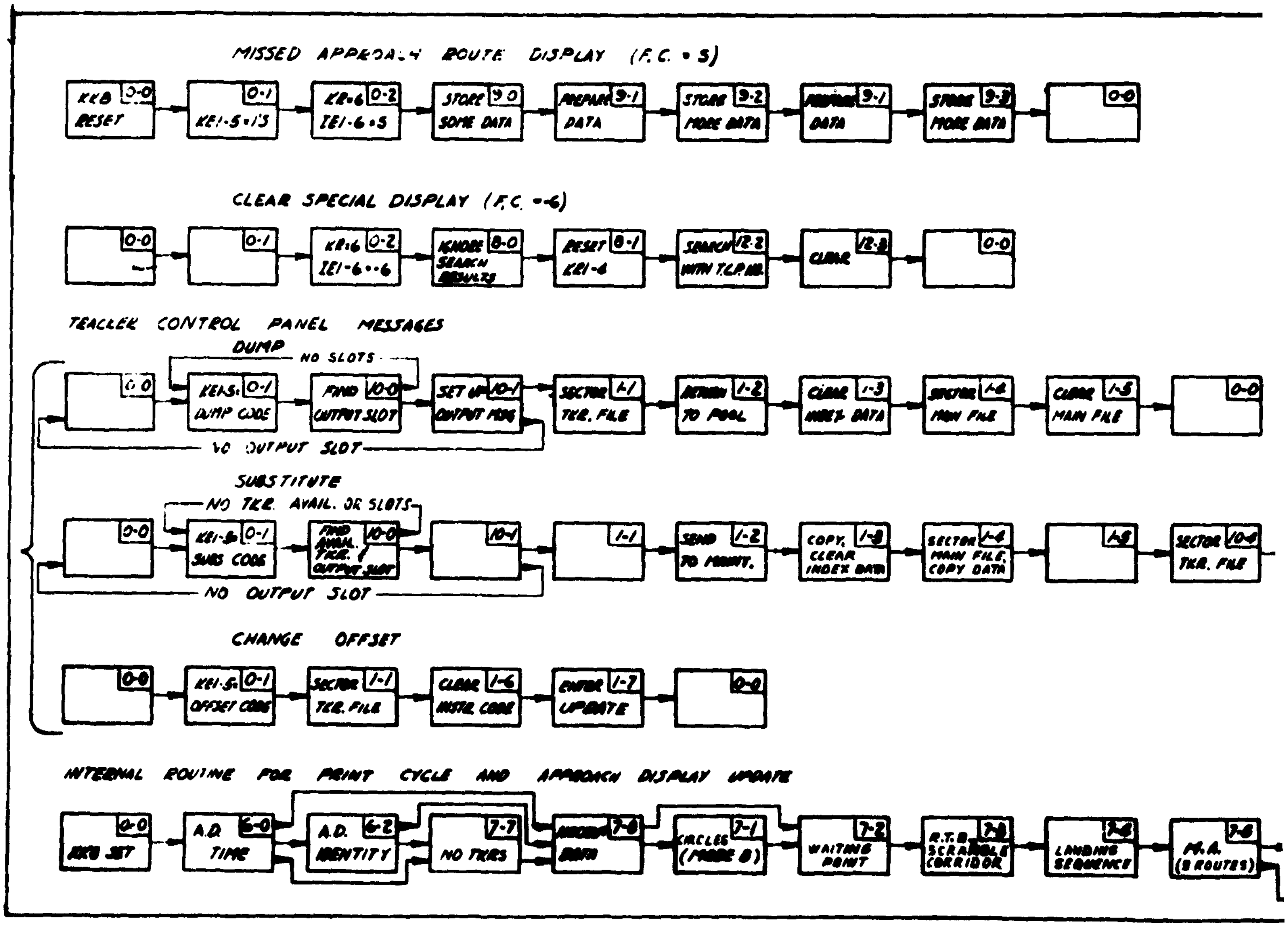


Figure 23. Video Track Programmer, Functional Flow Diagram

Sheet 2 of 3

1


MISSED APPROACH ROUTE DISPLAY (F.C. = 5)
KKB RESET 0-0
KEI-5=15 0-1
KB=6 IEI-6=5 0-2
STORE SOME DATA 9-0
PREPARE DATA 9-1
STORE MORE DATA 9-2
PREPARE DATA 9-1
STORE MORE DATA 9-3
0-0
CLEAR SPECIAL DISPLAY (F.C. = -6)
0-0
0-1
KB=6 IEI-6=-6 0-2
IGNORE SEARCH RESULTS 8-0
RESET KEI-6 8-1
SEARCH WITH T.C.P. NO. 12-2
CLEAR 12-3
0-0
TRACKER CONTROL PANEL MESSAGES
DUMP
NO SLOTS
NO OUTPUT SLOT
KEI-5 DUMP CODE 0-1
FIND OUTPUT SLOT 10-0
SET UP OUTPUT MSG 10-1
SECTOR TKR. FILE 1-1
RETURN TO POOL 1-2
CLEAR INDEX DATA 1-3
SECTOR MAIN FILE 1-4
CLEAR MAIN FILE 1-5
0-0
SUBSTITUTE
NO TKR. AVAIL. OR SLOTS
NO OUTPUT SLOT
0-0
KEI-5 SUBS CODE 0-1
FIND AVAIL. TKR. & OUTPUT SLOT 10-0
10-1
1-1
SEND TO PRINT. 1-2
COPY, CLEAR INDEX DATA 1-3
SECTOR MAIN FILE, COPY DATA 1-4
1-5
SECTOR TKR. FILE 10-4
CHANGE OFFSET
0-0
KEI-5 OFFSET CODE 0-1
SECTOR TKR. FILE 1-1
CLEAR MSTR. CODE 1-6
ENTER UPDATE 1-7
0-0
INTERNAL ROUTINE FOR PRINT CYCLE AND APPROACH DISPLAY UPDATE
KKB SET 0-0
A.D. TIME 6-0
A.D. IDENTITY 6-2
NO TKRS 7-7
7-0
CIRCLES (MODE B) 7-1
WAITING POINT 7-2
R.T.B. SCRAMBLE CORRIDOR 7-3
LANDING SEQUENCE 7-5
M.A. (3 ROUTES) 7-6

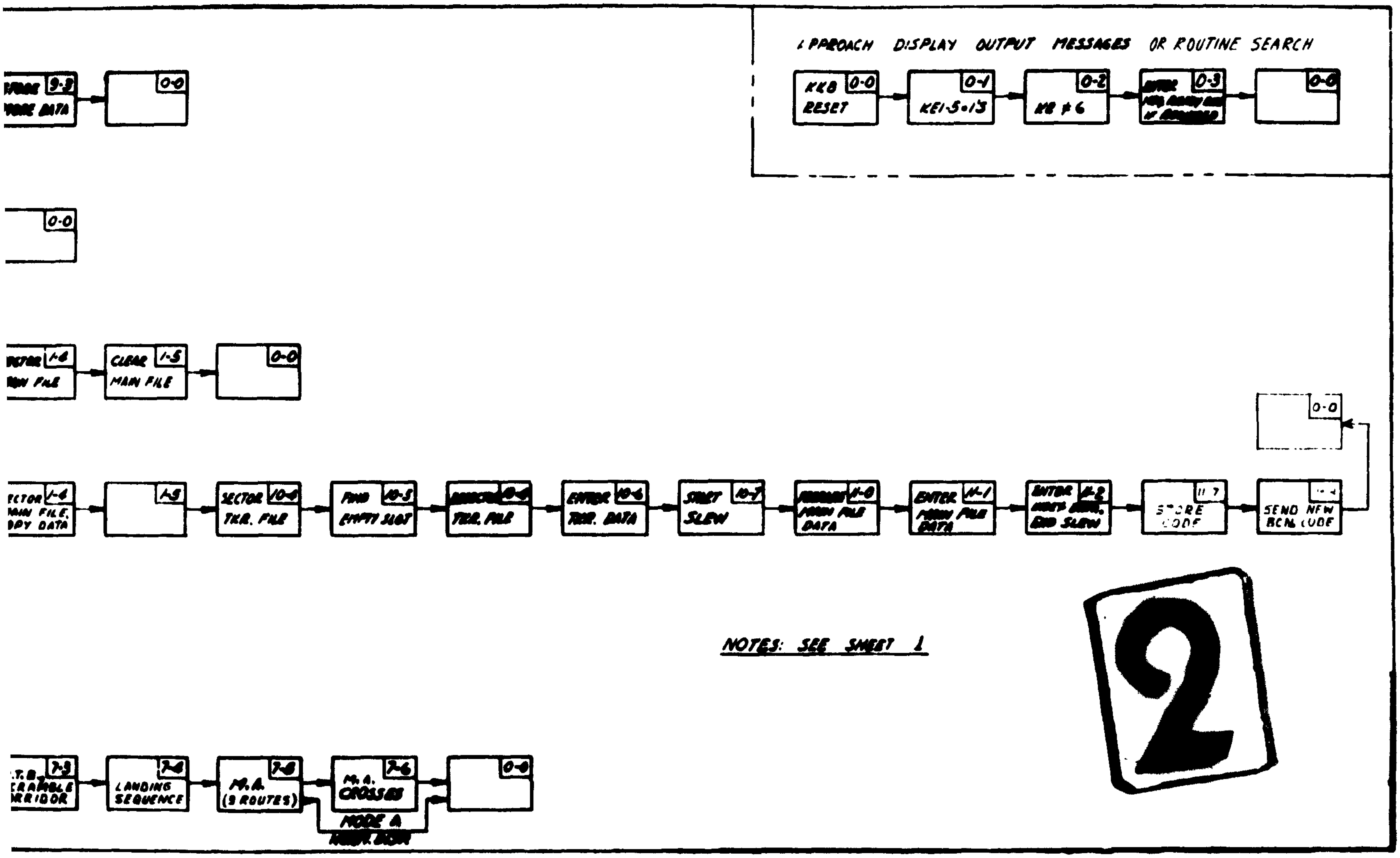


Figure 23. Video Track Programmer, Functional Flow Diagram

Sheet 3 of 3

An undervoltage control circuit was incorporated in the final packaging as stipulated by requirements imposed by the supplier of the magnetic drum subsystem. The circuit requires that +3 volts dc be applied prior to -15 volts dc. The circuit monitors the two potentials at all times, providing continuous control of the -15 volt supply in the event of failure of +3 volt supply.

The final design consisted of purchased modular power supplies compatible with system packaging. Voltages utilized changed during the course of circuit development. However, minimal changes were made by utilizing common design units in multiple. Requirements for +1.5 volts dc and -1.5 volts dc (except the magnetic subsystem) and plus and minus 18 volts dc were eliminated. A three-volt d-c supply supplanted a 1.5-volt unit. Current requirements rose rapidly as circuit reliability was improved and logic was added to implement new program requirements. When the ±18 volt d-c units were eliminated, consolidation of all logical circuits to -24 volts dc was accomplished and a common building block supply provided at seven amperes. Units comprising final design are listed as follows:

Power Supply	Specification
1.5 vdc at 4 amp. ±3% reg.	TES 1080
3.0 vdc at 1 amp. ±3% reg.	TES 1081
7.0 vdc at 4 amp. ±3% reg.	TES 1082
12.0 vdc at 2 amp. ±3% reg.	TES 1083
15.0 vdc at 5 amp. ±3% reg.	TES 1084
24.0 vdc at 7 amp. ±3% reg.	TES 1087

The power supplies for these units were packaged as follows:

Power Supply	Assy. No.	No. Used
1. 24 vdc TES 1087	3932	3
2. 15 vdc TES 1084	3941	1
3 vdc TES 1081		
3. 12 vdc TES 1083*	3947	1
12 vdc TES 1083		
4. 7 vdc TES 1082	3944	1
3 vdc TES 1081		
1.5 vdc TES 1080		

* Unit contains logic card in addition to supplies listed.

1.4.3.12 CABINET - The final design of the Video Track Programmer cabinet is basically similar to that of the Conditioner-Generator Unit cabinet (paragraphs 1.1.7.2 through 1.1.7.4). The incorporation of the Memory Drum System did not permit the same degree of uniformity as in the case of the Conditioner-Generator Unit. However, wherever possible, similar parts were used. An additional fan was incorporated at the top of the cabinet to cool the memory drum.

1.4.3.13 PROBLEMS - During the development of the VTP, several problems were encountered. One problem involved the design of the flip-flop. Because of variation in the speed of the response of transistors used in the flip-flops, a clock pulse of sufficient width to insure triggering the slowest flip-flop sometimes caused multiple triggering of the faster flip-flops. To solve this problem, an inductive delay of about one microsecond was added to the flip-flops to insure that retriggering would not occur within a normal clock interval. By this means, the difference in speed between slow and fast transistors was reduced to a satisfactory ratio.

An additional problem encountered was the deterioration of waveforms caused by stray capacitances in excess of those estimated in the original design. This problem was solved by increasing the bandwidth of the circuits by reducing the output impedance. Drivers were preloaded with external resistors as required and by adding or changing resistors on circuit cards as well.

1.4.3.14 ENGINEERING CHANGES - Many possible designs could have been chosen to carry out the functions required of the Video Track Programmer. The original intention, in accordance with prudent engineering, was to employ for the basic switching device a commercially available small drum with associated vacuum tube logic that would adequately meet the stated requirements and allow a reasonable growth factor. The final techniques and design resulted in the VTP performing the set of routines as documented on TIC Drawing 4594 and in figure 20 of this report. Consequently, additional switching, processing and storage requirements necessitated a complete change to a more comprehensive drum and associated logic. The advantage of changing from vacuum tube to semiconductor circuits was obtained at the same time.

During the development of the Video Track Programmer, the requirements and the direction of the development were changed several times by substantial additions and changes to GPL Specification 10000-523.

1.4.3.14.1 NUMBER OF OPERATING POSITIONS - During the initial phases of systems definition, a maximum of four operating positions was specified, whereas the final design had ten operating positions. In addition, the number and types of message to be processed were increased. Initially, the VTP was to

receive nine messages and was not required to send any messages. Revisions to GPL Specification 10000-523 have changed the message requirements so that the VIP must receive fourteen messages and must transmit six messages (4 basic types).

1.4.3.14.2 INCREASED CAPABILITY - During the design, all aircraft were considered to be assigned to landing sequence slots and the drum was to be ordered by landing sequence number to simplify other operations. When it was determined that outbounds, overflights and other aircraft not assigned landing slots were to be handled by the Video Tracking System, the plans for the drum configuration were changed to supply a capability of twenty aircraft without landing sequence assignments. Upon further study, the customer realized that more than twenty such aircraft might be involved, and Specification 10000-523 was changed so as to order the aircraft by Tracker number rather than by landing sequence number in order that the fifty available Trackers could be used for any type of traffic without limit.

1.4.3.14.3 CONTROL OF CHARACTER GENERATOR - Among the changes which developed as the system evolved, were several concerned with the data to be presented to the Character Generator. The early data format contained 16 characters. When the FAA determined that a seven-character identity would be required, this number was increased to nineteen characters. This, of course, required changes in the print-cycle logic. In addition, revised message structures were required, and this dictated that input-output logic also be revised.

1.4.3.14.4 NEW SYMBOLS - Changes were also made in the symbols to designate path-stretch instructions and to indicate the direction (sign) of error in time to fly. These changes required revision of the logic of the Type II Programmer in order to generate the new symbols.

1.4.3.14.5 COMMUNICATION BETWEEN VTP TYPE II AND DTS - Logic to implement communications with a Data Transfer System (DTS) was devised for use in the Type II Video Track Programmer, but before the unit was deleted from the system, this mode of communication was removed.

1.4.3.14.6 RAPID PRINT UP - During the initial phases of the Video Track Programmer design, the print operation was to be performed in conjunction with the computational program. The decision by the customer that a rapid print up of data was required necessitated a reexamination of the drum organization and revision to enable the print up to be completed in the allotted time (250 ms). In addition, a special routine for print-up operations was added to the program of the Video Track Programmer.

The original description of the data to be printed indicated that the correlation between the tracking gate and the character display format would be made by the proximity of the format to the tracking gate. It was later felt that this correlation was not adequate, and a requirement that a leader be generated between the tracking gate and the character display matrix resulted in additional design effort to generate the appropriate control and timing signals.

1.4.3.14.7 SELF TEST - As the programmer increased in complexity because of additional requirements and changes in concept, it became evident that built-in test programs were required in order that maintenance effort be reduced to a reasonable level. A total of fifteen states were added to the VTP for testing various data transfer operations. The functions performed by these test states are shown on the flow diagrams of TIC Drawing 4594. The addition of these test routines added approximately 1/2-chassis of electronic equipment in addition to the engineering efforts required to define the logic.

In order to meet the schedule, a drum subsystem and cards were purchased. As the requirement for three Video Track Programmers was revised to two VTP's, some of these cards and one of the drum subsystems ordered from Aeronutronics became surplus.

1.4.3.14.8 SPECIAL DISPLAY - It was determined later in the development program that in order for requests for special displays of the missed approach, landing sequence, or corridor types to be fulfilled in a relatively short time (10 seconds), it was necessary that the display be printed immediately after receipt of the message calling for the display. To add this override feature, additions to the logic of the VTP were required.

1.4.3.14.9 SIGNAL LEVELS - Specification 10000-523 was changed to require that the signal levels on the coaxial cables from the Air Traffic Control Data Processor be raised from 0 and 1 volt to +1 and -3 volts. This necessitated a reexamination of the circuits to determine whether they could be modified and a reexamination of the power supply requirements. Problems associated with the Character Generator also resulted in the expenditure of design effort.

1.4.3.14.10 TWO-POOL OPERATION - When it was determined that a two-pool mode of operation was required in the VTP, a toggle switch and approximately two logic cards of additional hardware were required to implement this change, in addition to the engineering effort required to modify the logical description in order to perform the fun ion.

1.4.4 RECOMMENDATIONS

1.4.4.1 GENERAL

A number of possible improvements in techniques and operational capabilities occurred to the designers while working on the finished VTP. These are enumerated as follows:

a. Add logic to modify the search for commands when a Tracker substitution is attempted and no Trackers are available. This would allow receipt of messages from the TDPG and local controller instead of only repeated attempts to substitute.

b. Add logic to insure that no output message is sent to the TDPG if a Tracker cannot be assigned because an operator already has twenty Trackers (an unusual but not impossible situation).

c. If recommendations a and b are added, the situation for no output message slots for dump and substitute should be looked into to prevent the same fault as corrected in recommendation a.

d. Add a more extensive input-output device to load the drum and indicate its contents.

e. Investigate providing redundant paths for basic logic. This could be an extensive program which would apply only to future design. Occasional component failures should not make the VTP completely inoperative.

f. Several test points and possibly lamps should be included in future models. Test points should also be added to cards if possible.

g. All voltage pins on card sockets should be insulated to prevent accidental shorting to adjacent driver outputs.

h. Better card testers should be supplied which require the addition of only a scope for complete card testing.

i. A system of logic error detection should be investigated for future design, including a panel of warning lamps to show the nature of the fault and if possible, its location.

j. A study should be made to determine whether the operational specifications should be modified so that a magnetic tape unit and a small high-speed storage unit could replace the existing drum. This system could result in lower costs, increased flexibility, and have the added feature that permanent magnetic records could be used to supplement or replace the printed flight strip records. The specifications most affected by such a change are those associated with the data printout operation.

1.4.4.2 **POWER SUPPLIES** - Recommendations given for the Conditioner-Generator Unit power supplies in paragraph 1.1.6.4 also apply to the Video Track Programmer.

1.4.4.3 **CABINET** - The use of a more powerful fan is recommended in order to avoid the necessity for two fans in the Video Track Programmer cabinet.

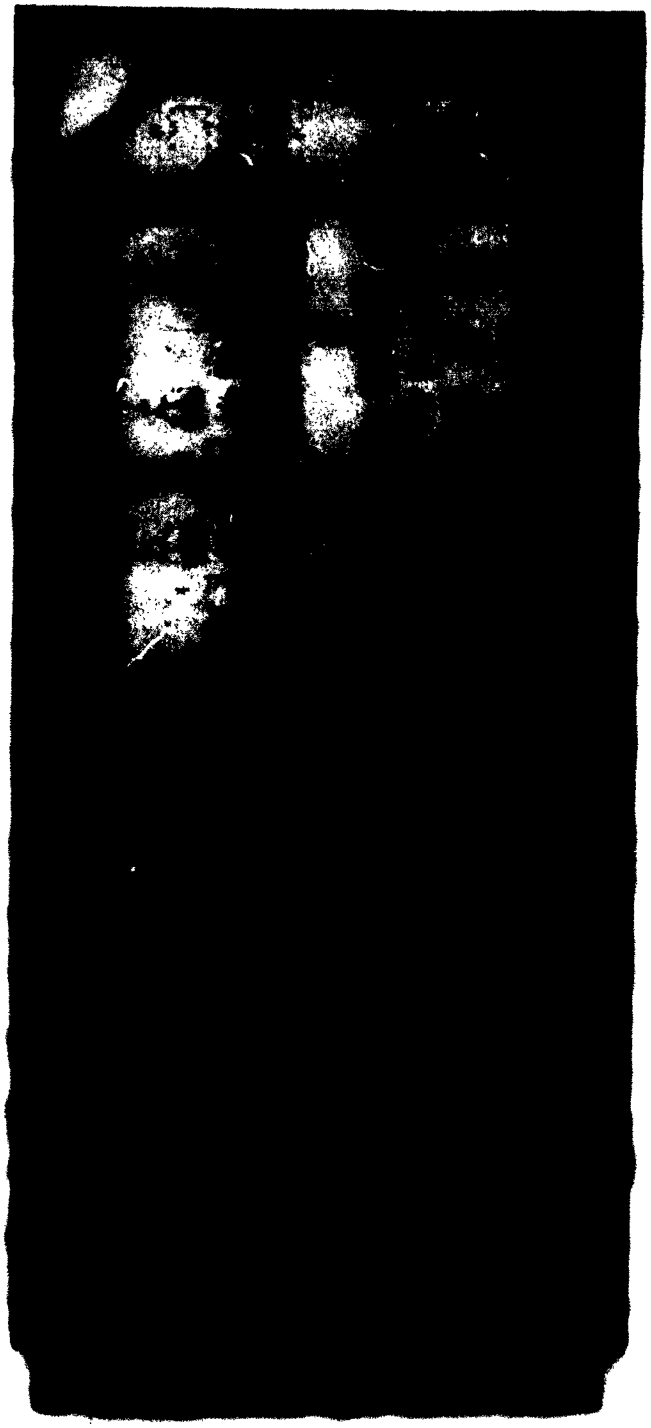


Figure 24. Video Track Programmer, Rear View

1.5 APPROACH DISPLAYS

1.5.1 DESIGN OBJECTIVES

Information to be displayed is first processed by the Approach Display Processor, a subassembly of the Conditioner-Generator Unit. Input data to the Approach Displays is converted from binary-coded decimal to 3-out-of-6 or 4-out-of-8 codes by the Approach Display Processor which acts as a buffer storage and control element between the Video Track Programmer and the Approach Displays. Two non-identical display units are provided, one for use in the PAR Console and the other for the Local Controller's Console. Design objectives for the two Approach Display assemblies are as follows:

1.5.1.1 DISPLAYS - The Approach Displays must display the identity and the time to fly for each of the five aircraft closest to touchdown. An additional display of the identity of the last aircraft to land must be provided on the Local Approach Display only. The background illumination for the displays must be adjustable to suit room lighting conditions.

1.5.1.2 TOUCHDOWN CONTROL - A touchdown control must be provided only on the Local Approach Display to initiate the updating of the display when an aircraft lands. This control must initiate a ladder-type operation wherein the sequence of all aircraft displayed remains fixed but each individual display is advanced one step toward the touchdown position. The aircraft data which was in the touchdown position is entered into the sixth display position (Local Approach Display only).

1.5.1.3 MISSED-APPROACH CONTROL - A missed-approach control must be provided only on the Local Approach Display. The control initiates the ladder-type updating of all aircraft displays except for the aircraft in next-to-land position; the information on this aircraft is not entered into the sixth position because the aircraft does not complete its landing.

1.5.2 DESIGN ALTERNATIVES

The following readout devices were considered:

a. An electromechanical indicator manufactured by the Union Switch and Signal Company.

b. An electromechanical device manufactured by General Railway Signal Company (GRS Indicator).

c. A non-mechanical device manufactured by Tasker Instruments Corporation.

The features considered in selecting the device were life time, noise, power required, availability, cost, complexity, size, illumination, and storage of last character entered. Union Switch units operate on binary-coded decimal input, whereas the GRS indicators utilize a unique binary code. The Tasker designed units would have required external storage control. However, noise, in contrast to that obtained with either of the mechanical units, would have been eliminated.

1.5.3 FINAL DESIGN (see figure 25 and 26)

1.5.3.1 CHOICE OF READOUT DEVICE - GRS indicators were selected for the readout device. This selection was based on their availability and their non-destructive readout in case of power failures. Tasker units were not in production form and did not have non-destructive readout.

1.5.3.2 INPUT CODING - Time-shared gating circuits for the alpha-numeric section (aircraft identity) permitted a reduction in input code lines from the display processor. A matrix circuit employed in the alpha-numeric section permitted reduction of driver transistors from 42 to 13, one for each row and one for each column. This was feasible because rows are updated sequentially. However, because the time-to-fly indicators (numeric indicators) are updated simultaneously, time sharing of code lines was not possible. A separate control circuit was therefore provided for each time-to-fly indicator.

1.5.3.3 POWER SUPPLIES - Power required for motor drive and transistor control circuits was obtained from a compact, minimal-regulation design. A stiff requirement was imposed by the motor starting-current surges. In particular, when the equipment is first turned on, up to 22 indicators may operate at one time and power-supply drain reaches a high peak surge value.

1.5.3.4 PULSING OF LAMPS - Some saving in heat dissipation and space was accomplished by pulsing background illumination lamps. This avoided rheostat power losses and the necessity for a space consuming variable transformer.

1.5.3.5 TRANSISTORIZATION - Transistor control circuits were mandatory because of insufficient space for relays or vacuum tubes.

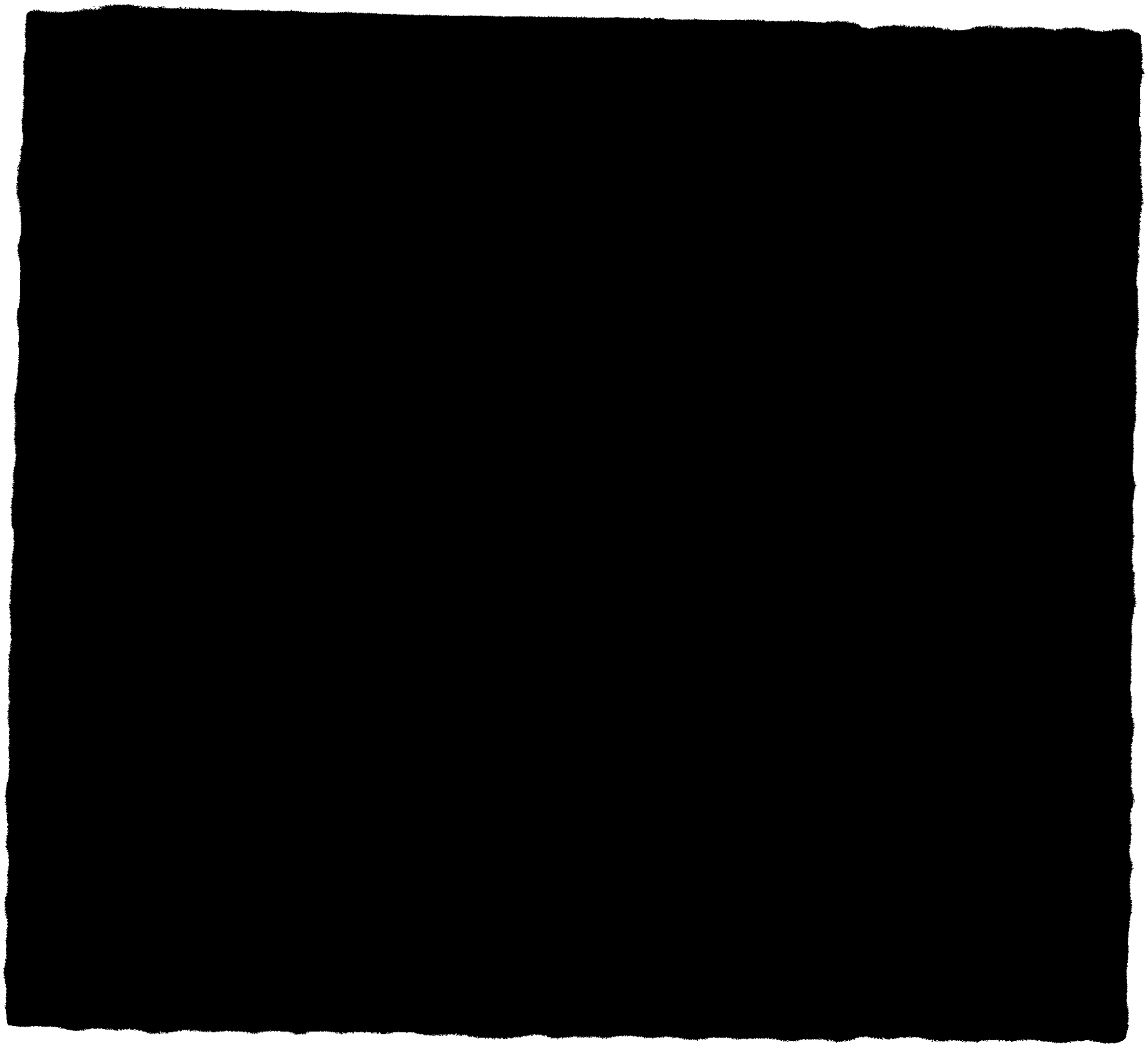


Figure 25. Local Approach Display

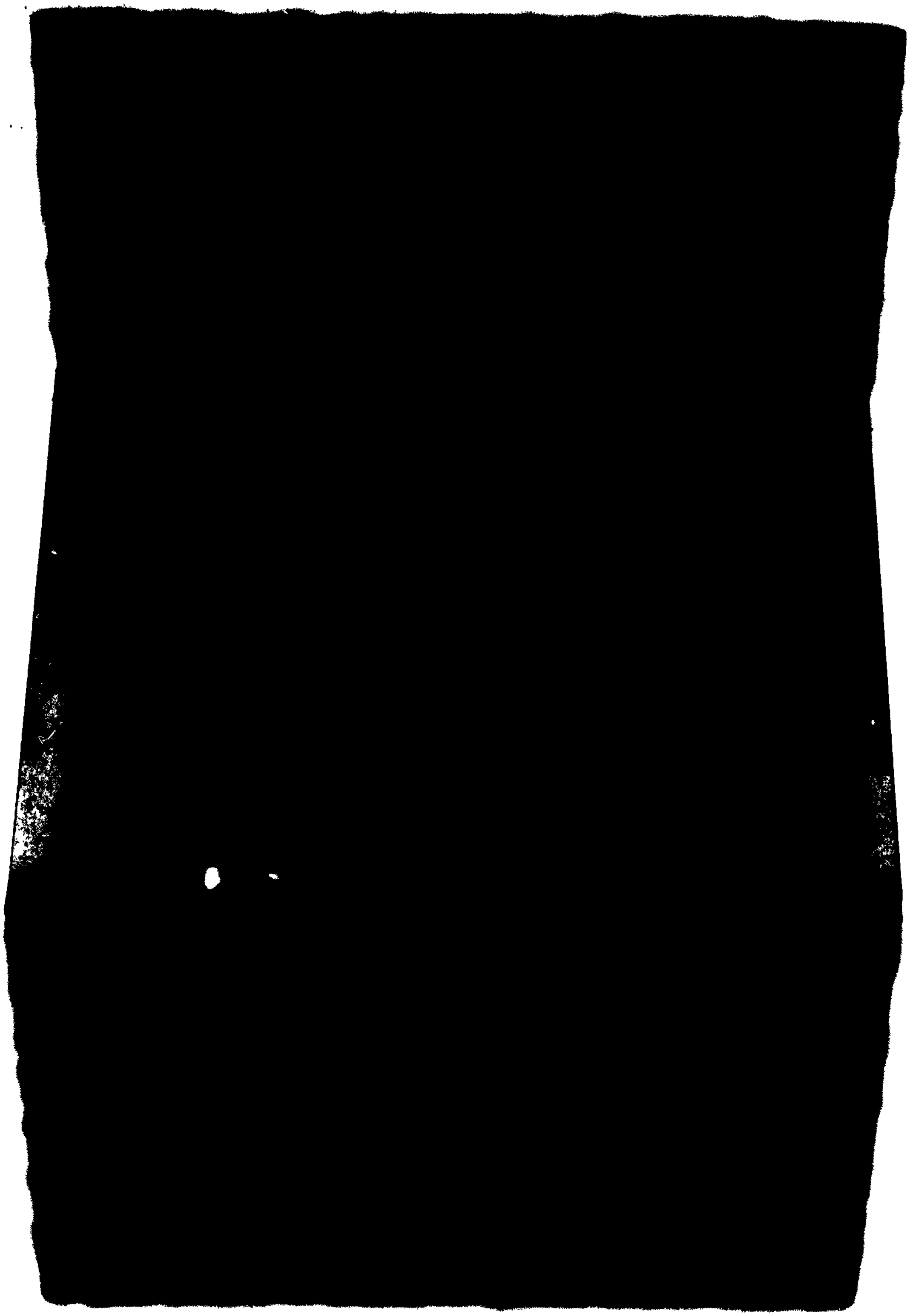


Figure 26. Local Approach Display, Rear View

1.5.3.6 <u>BRIGHTNESS CONTROL</u> - Circuits for remote brightness control were included in the design.

1.5.3.7 <u>REPLACEMENT OF INDICATORS</u> - Means for easily inserting and removing the indicator mechanism for maintenance purposes have been provided by a TIC designed tool.

1.5.4 RECOMMENDATIONS

1.5.4.1 <u>IMPROVEMENT OF NULL CHARACTERISTICS</u> - Erratic operation of indicators was noted during acceptance testing and attributed to the null characteristics of the GRS indicator commutator. An improvement can be accomplished by inverting the GRS motor drive logic. This change was not made during the Phase A program because of insufficient time.

1.6 PAR CONSOLE

1.6.1 DESIGN OBJECTIVES

1.6.1.1 GENERAL

The PAR Console is a remotely located display indicator console for use with either the PAR-1 or AN/FPN-16 radar systems (see figure 27). The necessary controls for remote operation of the above radar systems are included in the console. The console is designed for one- or two-man operation and contains a desk-high work shelf. Provisions have been incorporated for two sets of communications equipment, two sets of ash trays and coffee cup holders, a Wickes slave clock and an Approach Display electromechanical unit. Operating power of 115 volts ±10%, at 60 ±5 cps is required.

The purpose of the PAR console is to display both azimuth and elevation radar returns of aircraft with respect to their radar range. This is accomplished by using an Expanded Position Indication (EPI) type display presentation. The display indicator is a 21-inch direct-view storage tube with high light output and variable persistence. A polarized filter is also used to facilitate operation in a normally lighted room. The light output of the cathode ray tube, through the polarized filter, is 35 foot-lamberts minimum, and specular reflections are reduced by approximately 10:1.

Electronic mapping is utilized to produce the Expanded Position Indication (EPI) display from either PAR-1 or AN/FPN-16 remoted data. Circuits have been included for electronic generation and display of range marks, elevation glide slope cursor, azimuth course line cursor, upper ILS limit lines (elevation and azimuth), lower ILS limit lines (elevation and azimuth) and antenna position servo data. Operator controls have been incorporated to permit selection of:

a. Either a linear or near logarithmic time-base display

b. Independent control of range marks, cursors and ILS limit lines

c. Either an azimuth-elevation display or only an azimuth display

An Approach Display unit has been included for use with the DPC equipment. This display unit is mounted in the PAR Console at the left of the CRT Indicator Assembly and receives all inputs (except power) from the DPC equipment.

The interphone and communication speakers are located at the top of the PAR Console, to the left and right of the display cathode-ray tube. The communications equipment is located in the work shelf, as are the interphone switches and headset jacks. This equipment is supplied GFE and only its location was of concern in the layout of the console. In accordance with FAA requirements per

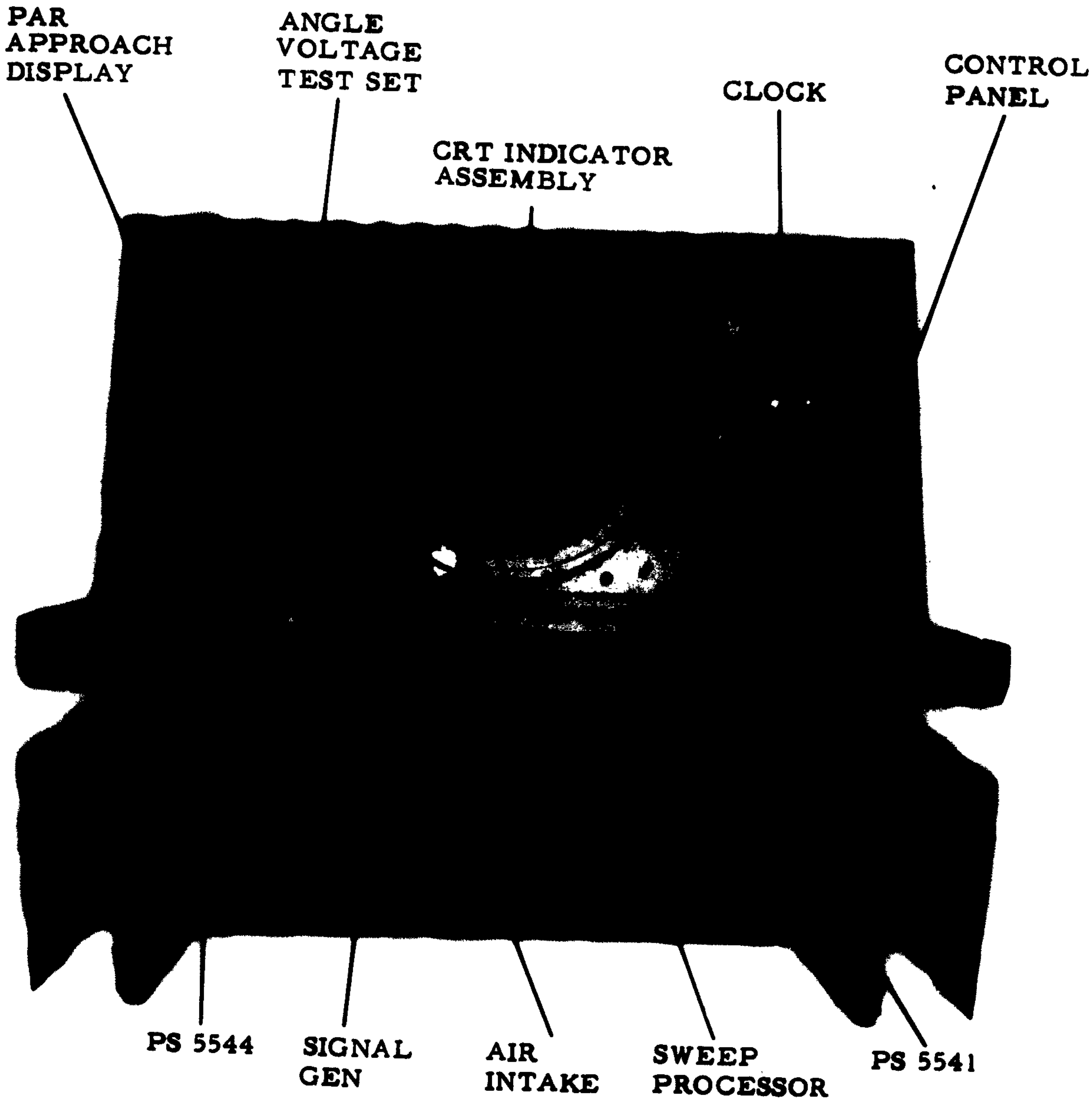


Figure 27. PAR Console

drawing FAA A-1-612231, the wiring provision for the equipment is via separate wiring channels which are free from all internal PAR Console wiring, and the component areas are shielded. The Wickes Slave Clock (Wickes Part No. 8940174) is located at the right of the cathode ray tube and is powered via a separate connector at the rear of the console.

The physical dimensions of the console were determined on the basis of operating environment and not compactness. As a result of past experience in console design and FAA human engineering studies, the front panel was placed at an angle of 80 degrees from horizontal, the work shelf was made 16 inches in width, the Control Panel was placed at the right side of the cathode ray tube, and all circuit cards were placed in two drawer type chassis below the work shelf and in the CRT Indicator assembly. The controls requiring access by both operators are located on the central CRT Indicator assembly, which houses the cathode-ray tube.

The PAR-1 or AN/FPN-16 remote equipment required for operation of the PAR console are as follows:

PAR-1 Remote Equipment - The only portions of the PAR-1 remoting equipment used by the PAR Console are the video and system trigger restoring circuits.

AN/FPN-16 Remote Equipment - The only portions of the AN/FPN-16 remoting equipment used by the PAR console are the video and angle voltage restoring circuits.

The remainder of the remoting equipments are not required when using the PAR Console, as the functions are duplicated or not needed.

1.6.1.2 SWEEP PROCESSOR

The design requirements for the PAR Console require that the following circuits be contained in the Sweep Processor Assembly.

a. Intensity Gate Generator

b. C & L Pick-off Circuits

c. +12 Volt and -12 Volt DC Regulator

d. Angle Volt Demodulator Circuits

e. Precision Delay Gate Generator

f. Sweep Generators

g. Map Generator

1.6.1.2.1 INTENSITY GATE GENERATOR - The Intensity Gate Generator must non-additively mix video mapping signals with the video input signals and additively combine these signals with an intensity gate. The composite video output must be inhibited by either the azimuth and elevation blanking signals of the PAR-1 radar or by the loss of C & L triggers from the AN/FPN-16 radar.

1.6.1.2.2 A2 C & L PICK-OFF CIRCUITS - Circuits must be provided for compatible operation with either the PAR-1 radar system trigger (A2) or the AN/FPN-16 system trigger and video mapping trigger (C & L). These circuits must be capable of "timing out" in the event of false triggering on the AN/FPN-16 L trigger.

1.6.1.2.3 REGULATOR, ±12 VOLT DC -This regulator must be capable of handling loads of up to 500 milliamperes. The regulation, as caused by the load variations, must result in a regulation of ±3 percent or better for both +12 volt and -12 volt potentials. The inputs to the regulator must be +24 and -24 volts dc.

1.6.1.2.4 ANGLE VOLT DEMODULATOR - The angle volt demodulator must be capable of buffering AN/FPN-16 angle voltage or generating angle voltage from PAR-1 reference and data triggers. It must be possible to operate with AN/FPN-16 or PAR-1 inputs by means of a selector switch.

1.6.1.2.5 PRECISION DELAY MULTIVIBRATOR - The precision delay multivibrator must be capable of generating a timing gate of approximately 123 microseconds which is delayed from the system trigger by 15 to 35 microseconds.

1.6.1.2.6 SWEEP GENERATORS - The sweep generators must be capable of generating x-axis and y-axis sweep voltages for either a linear EPI or a logarithmic EPI display. The selection of a linear or logarithmic range display must be accomplished by a front-panel switch.

1.6.1.2.7 MAP GENERATOR - Circuits must be employed to cause limiting of the elevation display between the angles of -1° and 0° and limiting of the azimuth display for angles greater than 4°. A selector switch must be provided to cause the entire elevation display to be blanked and the azimuth display to not be limited at 4°.

1.6.1.3 SIGNAL GENERATOR

Design requirements for the PAR Console required that the following circuits be contained in the Signal Generator assembly:

a. Cursor and limit line generators.

b. Range mark generator.

c. +12 Volt and -12 Volt d-c regulator.

d. Range mark blanking control assembly.

e. Relay gate buffer assembly.

f. Precision delay gate generators (as required).

1.6.1.3.1 CURSOR AND RANGE MARKS - Requirements for range mark accuracy and cursor slope accuracy must conform with the accuracy requirements of the AN/FPN-16 and PAR-1 radar sets. Each cursor limit line must be adjustable in slope and in range. Right-of-runway and left-of-runway operation must be selectable by switching.

1.6.1.3.2 RELAY GATES - Relay gate input signals, both AN/FPN-16 and PAR-1, must be converted to provide azimuth and elevation relay control in synchronism with radar angular information.

1.6.1.3.3 REGULATION - The ±12 VDC regulator requirements were determined by estimated load currents within the sweep generator assembly and processor assembly. A common circuit design providing +12 volts and -12 volts at 500 milliamperes was specified at ±3 percent regulation.

1.6.1.3.4 CIRCUIT CARDS - All circuits were to utilize the standard circuit cards used in the chassis designed for the TIC equipment. Wherever possible, circuits were to utilize transistors.

1.6.1.3.5 OPERATING POWER - All circuits were to operate from the following potentials.

1. +12 vdc and -12 vdc
2. +24 vdc and -24 vdc
3. +45 vdc and -45 vdc

4. + 100 vdc

5. + 150 vdc and - 150 vdc

1.6.1.3.6 TEST POINTS - Convenient front-panel test points were to be provided to enable circuit performance to be monitored while the console is in operation.

1.6.1.4 CRT INDICATOR ASSEMBLY

The CRT Indicator assembly is intended to contain the bright-display cathode-ray tube, the magnetic yoke, final deflection amplifiers, video amplifiers, display storage (erase) circuits, and the high-voltage power supplies necessary for the crt. It was desirable that the assembly be packaged in a manner which would facilitate maintenance and alignment.

1.6.1.5 CONTROL PANEL

Design objectives for the PAR Console Control Panel were as follows:

a. To contain the remote controls for both the PAR-1 and the AN/FPN-16 radar sets.

b. To contain the console display alignment controls.

c. To be compatible with the requirement for either one-man or two-man operation of the PAR Console.

1.6.1.6 LOW VOLTAGE POWER SUPPLIES

Load requirements for the PAR Console low-voltage power supplies were as follows:

Volts DC	*Regulation	Ripple	Load (ma)
-150	± 7.0%	±1.0%	15
-45	0.5	0.01	400
-24	1.0	0.01	2300
-12	3.0	0.01	400
+12	3.0	0.01	200
+24	1.0	0.01	2600
+45	0.5	0.01	400

+ 100	0.5	0.01	400
+ 100	7.0	1.0	400
+ 150	7.0	1.0	50

* No load to full load and ±10% of nominal input

In general, design alternatives were the same as for the Conditioner-Generator Unit power supplies. However, in order to achieve optimum accessibility and cooling, the chassis design of the Conditioner-Generator Unit power supplies was not used in the PAR Console.

1.6.1.7 MECHANICAL DESIGN (Refer to paragraph 1.6.1.1)

1.6.2 DESIGN ALTERNATIVES

1.6.2.1 SWEEP PROCESSOR

1.6.2.1.1 SWEEP GENERATION - In order to produce the sector type EPI presentation, the sweep generation and deflection system may utilize either a unipolar sweep generator and a deflection coil which is offset from the horizontal axis by approximately 10 degrees, or a crt-axis oriented deflection coil and a bipolar sweep generator may be used. The rotated (offset) deflection coil requires alignment marks etched into the face plate and special circuits to cause interaction between the time base and the expansion sweep in order to obtain vertical range marks. This interaction is dependent on the length of the time-base sweep and the expansion of the vertical sweep. The crt-axis oriented deflection coil and bipolar sweep generator require that the vertical sweep generator produce both negative and positive going sweeps as a function of the modulating angle voltage input. However, no alignment marks are required on the face plate of the display.

The sweep generator may be combined with an a-c deflection amplifier, or d-c deflection amplifier to drive the deflection coil single ended or in push pull. This technique would require fewer circuits than other techniques.

The sweep generator may be separate from the d-c deflection amplifier. This technique offers the greatest flexibility in expanding the uses of the crt and affords multiple inputs to the deflection system.

1.6.2.2 SIGNAL GENERATOR

1.6.2.2.1 RANGE MARK GENERATION - The range mark oscillator may be be a crystal-controlled oscillator, an l-c oscillator, or a free-running multivibrator. The crystal-controlled oscillator is the more accurate but requires up to four cycles to stabilize when gated on and off. The l-c oscillator has the same stabilizing problem when gated but can be made to settle after one cycle. The multivibrator oscillator is most subject to frequency drift with input voltage and temperature variation but is most easily gated without changing frequency.

1.6.2.2.2 CURSOR GENERATORS - The following types of cursor generator were considered as suitable:

a. Miller-integrator operational amplifier sweep circuits and comparator blocking oscillator.

b. Bootstrap sweep circuit and comparator blocking oscillator.

1.6.2.3 CRT INDICATOR ASSEMBLY

1.6.2.3.1 LIGHT FILTER - The filter should be a dual safety plate and specular reflection attenuator. An etched map may be placed on the face plate as an alignment aid. The etched map would contain ILS limit lines, angle lines and constant altitude lines. A separate safety plate could be used in addition to the filter and the filter might not be circular polarized. This technique would enable selection of a color filter and would not attenuate the light output of the crt as much as the polarized filter. The safety plate may be combined with the filter and an etched map could be used if desired.

1.6.2.3.2 VIDEO AMPLIFICATION AND NEGATIVE HIGH-VOLTAGE POWER SUPPLY - The video base line intensity pulse, range mark pulses, video, cursor pulses, and ILS limit cursor pulses could either be mixed prior to the final video amplifier or could be summed at the input to the final video amplifier. A separate video mixing circuit degrades the system video response because of additional stages but permits high impedance non-additive mixing which is free from pickup, and requires fewer video cables to the crt indicator. Mixing at the input to the final video amplifier adds cables between chassis of the console and requires additional low-impedance driving stages. Low-impedance non-additive mixing must be used to prevent electrostatic feedback loops.

The output of the video amplifier could drive either the control grid or cathode of the write gun. Also, the output could be either a-c or d-c coupled. To drive

either element of the crt directly would require that the flood gun elements of the tube be operated at approximately plus 4KV and the view screen at plus 14KV. Driving the write gun grid/cathode via a coupling capacitor places the flood gun cathode near ground potential. Driving the grid rather than the cathode requires less pulse power but requires better negative power-supply filtering.

1.6.2.3.3 VIEW-SCREEN POWER SUPPLY - The view-screen power supply may be either a 60-cps power supply, an r-f power supply, or a gated r-f power supply. The 60-cps supply, although the most straightforward in design, is the largest, requires excessive shielding against radiation into the crt, and is not easily pulsed off and on, as is required to maintain contrast ratio at short persistence settings of the storage tube. The r-f power supply requires less shielding and is easier to gate off and on but requires excessive power while gated off. The gated r-f power supply requires excessive build-up time of the high voltage after being gated off.

1.6.2.4 CONTROL PANEL

The control panel should contain only operator controls or frequently used maintenance controls. Studies indicated that only operator controls should contain knobs and that these knobs should not contain locking devices. Maintenance controls should be screw-driver controls or locked controls.

1.6.2.5 LOW VOLTAGE POWER SUPPLIES

Magnetic, transistor and vacuum-tube regulated power supplies were considered. Other considerations were the same as the design alternatives for the Conditioner-Generator Unit power supplies (paragraph 1.1.6.1).

1.6.2.6 MECHANICAL DESIGN

Standard cathode-ray tube consoles are designed with a front panel slope of 70 degrees from horizontal using a 14-inch work shelf depth. Human engineering studies conducted concerning this console indicated the front-panel slope should be 80 degrees from horizontal in order to place the center of "cone of vision" at the center of the 21-inch cathode-ray tube. Studies also indicated that the work shelf should be 16 inches in depth because of the communications equipment.

1.6.2.6.1 CONSOLE DESIGN - The determining factor in the size of the PAR Console was the requirement to accommodate two operators sitting side by side. In other respects, the mechanical design of the console was determined by exact specifications as to the shapes and locations of components.

1.6.3 **FINAL DESIGN** (see figure 31)

1.6.3.1 **SWEEP PROCESSOR**

1.6.3.1.1 **INTENSITY GATE GENERATOR** - This card provides a 0 to 4-volt video intensity pulse to the video amplifier with video signals additively mixed on top of the intensity gate. The level is controlled by the Brightness control on the CRT Indicator assembly. The pulse is 123 microseconds long but is limited by the varying map L trigger to less than 123 microseconds at various locations on the crt face. PAR-1 radar blanking signals, which are received when switching from azimuth to elevation, are amplified and used to inhibit the intensity gate during this time. Amplifier Q4 buffers and inverts signals which determine when the video and intensity gate may be enabled. The sweep gate, except when inhibited completely by the elevation control switch, or partially inhibited by the azimuth and elevation blanking voltages or the 200 microsecond map-controlled multivibrator (located on the A2-C & L Pickoff Buffer assembly card), generates the intensity gate. The range marks are mixed with the radar video and the cursor video coming into the card. A squelch pulse is used to eliminate A2 or C & L pickoff triggers from composite video. Different intensity gate levels are required for the logarithmic and linear presentations. The proper levels are provided by the sweep generator No. 2 circuit card.

1.6.3.1.2 **A2-C & L PICKOFF BUFFER ASSEMBLY** - The A2-C & L pickoff buffer card is designed to generate a system trigger for the indicator and to produce a driving gate for the intensity gate generator card circuits (paragraph 1.6.3.1.1) in conjunction with the time-variable map L trigger. An input amplifier accepts trigger pulses of 12-volt minimum amplitude and one-microsecond width from the PAR-1 or AN/FPN-16 Radar systems.

The r-c coupled output is used to trigger a 200-microsecond gate multivibrator. This gate is variable in width as a function of time between the system trigger and the map trigger. The output of the multivibrator drives a one-microsecond blocking oscillator circuit to give a 0 to 12-volt system trigger. This system trigger is used as a master timing source for the indicator circuits. It turns on the horizontal sweep, range mark oscillator, cursor generators, and map generator.

1.6.3.1.3 **REGULATOR ASSEMBLY, 12-VOLT** - This card contains two regulators for the +12 and -12 volt d-c operating potentials. No filtering is necessary at the inputs, since the regulators operate from regulated 24 volt supplies. Standard series regulators are used which are capable of handling up to one ampere. An adjustment range of several volts is provided for each supply. Over-current protection is provided by use of series limiting resistors and over-

voltage protection is performed with Zener diodes. Current multipliers are used to drive the series regulators and a feedback loop controls the output voltage. Output filtering of 27 microfarads is provided for each supply. The regulation requirement is ±3 percent for 20 to 500 milliamperes change in load. Actual load regulation is better than 0.5 percent to 600 milliamperes. Since the 24-volt supply is used as an input, the 12-volt regulators are insensitive to line voltage variation and operate with approximately 30 percent variation in input voltage. Ripple is below noise level and transient response is better than the 200-microsecond requirement when switching from 20 percent to 90 percent of load capability.

1.6.3.1.4 ANGLE VOLTS DEMODULATOR NO. 1 - This card is used to generate the angle volts for the PAR-1 Radar. The remoting system provides a reference trigger delayed from the system trigger by approximately 250 microseconds. The data trigger is delayed in time from the reference trigger by from 50 to 150 microseconds and is continuously variable. Fifty microseconds corresponds to 0 volts or -5 degrees for azimuth and -1 degree for elevation. One hundred and fifty microseconds corresponds to 20 volts or +15 degrees for azimuth and +6 degrees for elevation.

The reference trigger is limited, then inverted and used to set the data multivibrator. The data trigger is limited, then inverted and used to reset the data multivibrator. The variable-width gate from the multivibrator turns on a sweep generator which charges a capacitor to a voltage proportional to the delay between the reference and data triggers. The scale factor of this sweep is controlled by the ANGLE VOLT GAIN Control located on the PAR Console Control Panel. A capacitive network compensated for non-linearity at the upper end of the sweep ramp. Since a decreasing voltage is required when the time delay between the reference and data trigger decreases, the charging capacitor must be discharged before each sweep. A transistor switch performs this function. The unfiltered angle voltage is provided through a two-transistor compound feedback buffer. The variable data gate is also provided as an output to the angle volts demodulator No. 2 card.

1.6.3.1.5 ANGLE VOLTS DEMODULATOR NO. 2 - This card is used for both AN/FPN-16 and PAR-1 operation. When used for AN/FPN-16 operation, an angle voltage varying from 2 to 52 volts is applied to an AN/FPN-16 Angle Volt Gain control located on the PAR Console Control Panel. Attenuated angle voltage is obtained from the wiper of this potentiometer for the angle volts demodulator No. 2 card. A compound feedback buffer provides the output. The d-c level is adjusted by providing a d-c voltage from the AN/FPN-16 Angle Volt Bias Control on the Control Panel. A constant-current transistor adjusts the d-c level by controlling the current through a resistor.

For PAR-1 operation, the unfiltered angle voltage from the angle volts demodulator, No. 1 card is used as an input. A grounded-base amplifier places the angle volt signal on a holding capacitor. An r-c network limits the angle voltage sweep to less than 30 volts. A transistor switch cuts off the amplifier during the time the charging capacitor in angle voltage demodulator No. 1 is charging to a new value. This accomplishes smoothing and eliminates holes in the angle voltage output. The PAR-1 angle voltage output is buffered through a two-transistor compound feedback buffer. The d-c level is controlled by the PAR-1 Angle Volt Bias Control located on the Control Panel of the PAR Console. An Angle Voltage Phase Adjustment Potentiometer provides smoothing feedback to the sweep generator located on the angle voltage demodulator No. 1 card.

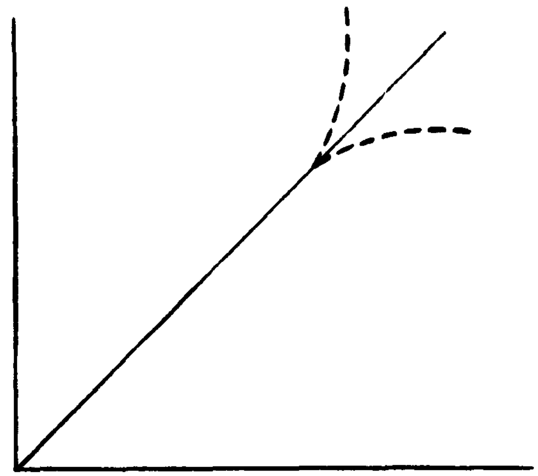
1.6.3.1.6 PRECISION DELAY MULTIVIBRATOR - One precision delay multivibrator is used to control the cursor generators and another controls the range-mark delay. This arrangement allows the cursor to be adjusted to any desired touchdown point, while maintaining fixed range data.

Control of the cursor and range-mark delay multivibrators is accomplished by potentiometers on the Control Panel. These may be adjusted and locked in the calibrated position.

1.6.3.1.7 SWEEP GENERATION

The sweep generator was designed to be independent of the deflection amplifier system. The sweep generator was also designed to be bipolar. The deflection amplifiers are d-c amplifiers. The above combination of sweep generator and deflection amplifier provides the greatest versatility for usage of the PAR equipment in other applications.

1.6.3.1.7.1 SWEEP GENERATOR NO. 1 - This card generates the time base sweep (linear or logarithmic). A sweep gate, 123 microsecond long, is received from the sweep precision delay multivibrator. The sweep gate drives an amplifier which controls a six-diode switch. The six-diode switch, during dead time, discharges any d-c potential which exists across the charging capacitor of the sweep generator. Several sweep circuits in other circuit cards of the Sweep Processor chassis are also controlled by the six-diode switch gates. The sweep generator circuit produces a time-base sweep which is ultra-linear and may be controlled to give either a positive or negative roll off as shown in the following graph. The linearity is limited only the accuracy of passive resistor components.



Sweep Roll-Off Characteristics

The time base gain control provides a d-c voltage which controls the charging voltage of the sweep for logarithmic-linear sweeps. The Log-lin switch on the Control Panel controls the type of sweep by activating the K1 Log-lin relay on this card. The sweep generator is temperature compensated by diode CR8 to reduce d-c drift due to variation of V_{BE} in the sweep-generator input transistor.

1.6.3.1.7.2 SWEEP GENERATOR NO. 2 - The Sweep Generator No. 2 card contains the expansion or vertical sweep generator. A diode switch is driven by the ±24 volt signals received from sweep generator No. 1. The sweep circuit is identical to that used on sweep generator No. 1. A low-impedance temperature compensated compound buffer provides the output. The charging voltage (angle volts) is variable from 0 to 20 volts and is obtained from the angle volts demodulator No. 2 card through a buffer. Compensation is provided for linear and logarithmic sweeps. The d-c level of the charging voltage is adjustable by means of the slope control on the front panel by controlling the current through a transistor.

1.6.3.1.8 MAP GENERATOR - This card controls the video map on the Tonotron crt by shutting off the video intensity pulse at a preadjusted point on the horizontal and vertical sweeps. This card uses the same form of comparison and output pulse generation as the cursor generators (paragraph 1.6.3.2.1). A sweep-start level control potentiometer provides a negative control voltage. When the 123-microsecond sweep gate turns on the clamping switch, the transistor collector voltage increases from the variable negative offset voltage (controlled by Sweep Start Level control) to 0 volts. This allows separate level shift of either the Log Map Sweep or the Linear Map Sweep (whichever has been selected by the Log-Lin Relay Switch). A compensation adjustment is incorporated for matching the Log

Map to the Lin Map Display. The sweep is level shifted through a grounded-base current amplifier. A transistor buffers the level-shifted map sweep output to the Az-El Relay.

The map sweep returns to this card from an Az-El Relay for use in elevation mapping. This sweep is compared against the elevation angle volts sweep to operate elevation map limiting triggers. The elevation map limiting is variable for the first 20 percent of the 123 microsecond sweep time. Since the azimuth map limiting point is constant, a single potentiometer on the Control Panel provides a d-c voltage which is compared against azimuth angle volts sweep to give map limiting when the Az-El relay switches to azimuth.

The comparator operates as a current switch supplied by a constant-current source which continuously provides 7.45 milliamperes to the switching transistors. The transistor switch triggers a blocking oscillator which produces the one-microsecond positive pulse. The pulse is inverted, limited to a twelve-volt amplitude and used as a map L trigger.

The blocking oscillator transistor also receives an input trigger at the end of the 123-microsecond gate through a switch-inverter transistor. The map L trigger provided at this time, shuts off the display at the end of 123 microseconds (ten miles).

Map limiting may be supplied externally by providing an input to the A2-C & L trigger card and turning the PAR Console map controls on the Control Panel full clockwise.

1.6.3.2 SIGNAL GENERATOR

1.6.3.2.1 CURSOR GENERATOR AND LIMIT LINE GENERATORS - Bootstrap sweep circuits were utilized rather than operational amplifiers because sufficient accuracy could be obtained at lower cost.

The design of the sweep circuits utilizes two precision sweep generators. One is held fixed in slope and d-c offset and the other is variable, being modulated in slope by angle voltage. Both sweep circuits are switched on and off by six-diode switches which accomplish rapid turn-on and turn-off. The output of each sweep circuit is applied to a comparator which switches its output level when the sweep voltages are equal in amplitude. This level change is differentiated and the resulting pulse is used to trigger a one-microsecond blocking oscillator. The cursor output is mixed with the range mark output and added to the intensity gate.

The elevation glide-slope line and azimuth course lines are generated using the same circuits by switching the input signals of dual emitter-follower circuits which control the slope of the precision fixed sweep. These emitter followers

are switched on alternately by an azimuth-elevation relay, thus providing cursor generation for both azimuth and elevation displays. Azimuth and elevation limit-line pulses are inhibited until levels set by the respective limit-line start controls, together with the cursor 23-microsecond precision delay gate, enable the limit-line cursor blocking oscillators to respond to input triggers. Elevation glide-slope and azimuth-centerline cursor start points are set by respective azimuth and elevation cursor offset controls. All the cursor generators are gated by a cursor precision delay multivibrator. An emitter-follower and double-inverter circuit is provided on the relay gate buffer card to supply the current required for the six-diode switches in the cursor generators. Rapid-switching medium-power transistors were utilized to provide accurate timing of the cursor sweep generators with negligible transient disturbance of the cursor sweeps.

1.6.3.2.2 RANGE MARK GENERATOR - A gated free-running multivibrator turned on by the angle mark precision gate was selected for the range mark generator because it is less complex than a master oscillator-Schmitt trigger arrangement. Adequate stability was achieved to satisfy system requirements.

A blocking oscillator is triggered by the free-running multivibrator gate. Range-mark width is held to 0.2 microsecond to provide sharp range lines on the Tonotron display. Range mark start is adjustable with respect to the time-base sweep origin by the Range Mark Precision Delay control. Spacing between marks can be adjusted by a variable resistor located on the range mark generator card.

Presentation of any number of range marks between 6 and 12 is obtained by adjustment of the Control Panel Range Mark Gate Length control. Range mark gate length is nominally 123 microseconds in duration. A precision delay gate multivibrator card is utilized to provide the stable gate required for this function. The brightness of the range marks is varied by use of the Range Mark Intensity control on the Control Panel.

A Range Mark Blank-Bright servo switch and a Range Mark Ratio control are located on the Control Panel to permit the operator to adjust the ratio of brightness of the range marks between the displayed elevation antenna position in azimuth and the displayed azimuth antenna position in elevation to the average range mark brightness. The ratio control can be used to either intensify or de-intensify the ratio of the brightness of the range marks during the interval of the antenna position displays to the average range mark brightness by at least 10 to 1. The Blank-Bright switch reverses this brightness ratio. This is accomplished as follows:

The range mark generator No. 2 circuit card contains summing circuits which compare antenna scan position (provided by angle volts) and antenna servo position (proportional to antenna look-angle with respect to horizontal and vertical planes through the antenna mount) which are used in the blank-bright control circuits. Elevation servo position data for the azimuth antenna is switched by relay control when presenting elevation scan data, and azimuth servo position data for the

elevation antenna is switched in when presenting azimuth scan data. An operational amplifier in the antenna scan input serves to isolate the gating circuit from the angle volt demodulator and adjusts the angle voltage scale factor. Summed antenna scan and antenna servo data levels produce two simultaneous gates which reverse state whenever the antenna scan and antenna servo position voltage levels are equal. As one scan is made (elevation or azimuth), two gate level shifts occur, corresponding to two antenna servo input levels. In response to the two levels, control gates for bright and blanked sectors are generated. These gates outline a display sector which is proportional to the radar beam width in both the elevation and azimuth displays. Relative blank-bright ratios are selected by the setting of the Range Mark Ratio control which, through the Range Mark Blank-Bright reversing switch, permits selection of the gates generated by range mark generator No. 2 circuits. These signals control range mark intensity by bias control of the output transistor of the range mark generator. Intermediate range mark brightness values are obtainable to suit all display conditions by adjustment of the Range Mark Ratio control.

1.6.3.2.3 <u>REGULATORS, 12 VOLT DC</u> - A transistor series regulator is utilized in the design of the 12 volt regulators. A Zener diode is utilized as a reference and power is obtained from the 24 volt d-c power supplies. Three transistors for each regulator provide adequate gain. Current-limited output is accomplished by series limiting resistors and is regulated to ±3 percent. Zener diodes are incorporated on the output of each regulator. These protect the load circuits against excess voltage of either positive or negative polarity in the event of regulator failure.

Adequate heat-sink area was provided for the series regulators to ensure stability under high ambient temperature conditions at full load.

1.6.3.2.4 RELAY GATE BUFFER ASSY - Relay-gate data levels for the AN/FPN-16 and PAR-1 radar sources differ. A switch is incorporated on the relay gate buffer circuit card to provide for proper d-c level shifting and for the phase inversion necessary for operation with either the AN/FPN-16 or PAR-1 radar.

A single transistor is used to drive all azimuth-elevation relays on the control panel in synchronism. A shunt diode across the relay coils provides transient protection for the driving transistor. Current limiting is accomplished by a series resistor.

An emitter-follower buffer is incorporated on the relay gate buffer card in order to supply the current for the cursor 23-microsecond precision delay signal which is applied to the limit-line generators.

Cursor generator six-diode switches are supplied two current gates by circuits of the relay gate buffer assembly. These switching circuits are designed for rapid recovery time. They utilize hold-off diodes to eliminate storage effects in the transistors. A double inverter provides the required gate and inverted gate output. Both gates are driven by the cursor precision delay gate multivibrator card and are nominally 123 microseconds in length.

1.6.3.3 CRT INDICATOR ASSEMBLY (see figure 28)

The present CRT Indicator assembly eliminates many of the disadvantages inherent in former designs. The display utilizes a large-screen storage-type cathode-ray tube. High-voltage pulsing techniques are used to obtain maximum contrast ratio and high brightness. The display may be viewed easily in a well lighted room. The glide slope, runway centerline, ILS safety limit lines, and range marks are generated electronically in order to eliminate parallax errors between overlay reticules and targets.

The CRT Indicator assembly is mounted on a sliding track so that it may be extended forward from the console frame for maintenance and alignment.

The assembly is almost completely transistorized. The following circuits are not transistorized:

a. The high-voltage regulator and diode in the video coupling circuit of the -4 kv supply

b. The rectifiers in the voltage-doubler circuit of the + 10 kv supply

c. The Nuvistors and the pentode used in the high-voltage squelch circuit of the + 10 kv supply

In these cases, except for the rectifiers, tubes were chosen because of the voltage levels required. Vacuum rectifiers were used for the following reasons:

a. Ability to withstand current surges better than the present semiconductor equivalents.

b. Available space in the high-voltage package

c. Economy

The range-sweep deflection amplifiers are located close to the crt deflection coil to minimize capacitive effects on the deflection amplifier outputs. Isolating the deflection amplifiers from the generator circuits also minimizes radiation pickup.

The video amplifier card and the erase oscillator cards are also located in the CRT Indicator assembly, close to their output terminations at the crt and high voltage supplies.

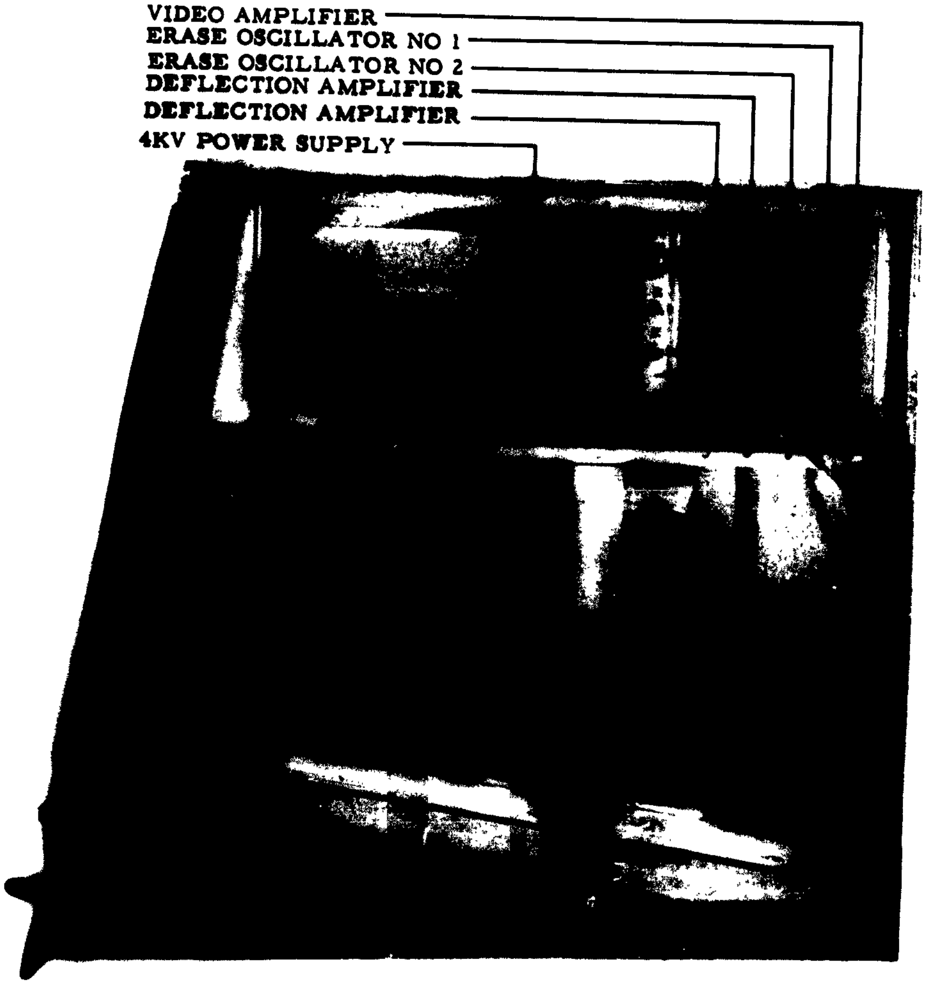


Figure 28. CRT Indicator Assembly

1.6.3.3.1 <u>POLARIZED FILTER - FACE PLATE</u> - The filter specified was a 1/4 inch thick safety plate and circular polarized filter. No etched marks were placed on the surface of the glass filter, but alignment marks were placed on the dust ring adjacent to the crt. This design utilizes the same filter plate as used in the PPD Display Module. The alignment marks are not necessary on the face plate, as all mapping is accomplished electronically and display-overlay matching is therefore not required.

1.6.3.3.2 <u>VIDEO AMPLIFICATION AND NEGATIVE HVPS</u> - A separate video mixer was used to mix the time-base intensity pulse, range marks, video, cursor pulses and ILS limit cursor pulses. The negative high-voltage power supply (figure 29) was designed to operate the crt write gun cathode at a negative 4000-volt potential. The power supply was also designed for write-gun grid drive signals. Thus, the high-current elements of the crt (flood gun and collector mesh) are near ground potential.

1.6.3.3.3 <u>VIEW SCREEN POWER SUPPLY</u> - A gated r-f power supply (figure 30) was selected because of the ease of gating, low d-c input power drain during gated off periods, and ease in shielding.

1.6.3.4 <u>CONTROL PANEL</u>

In its final design configuration, the PAR Console Control Panel contains most of the operating controls and all of the alignment controls. Five of the operating controls: Antenna Servo, IF Gain, Video Gain, Video Intensity, and Focus have been located on the CRT Assembly where they are convenient for either one or two-man operation.

Knobs were incorporated on all controls. Locking knobs are incorporated on the maintenance controls. This design was based on the ability of the operator to make minor maintenance adjustments.

In addition to operating and alignment controls, the Control Panel contains a bank of relays which perform the following switching operations:

a. Switch radar position information inputs to the console Sweep Generator circuits.

b. Switch power supply voltages within the console.

c. Activate the Angle Voltage Test Set for alignment purposes.

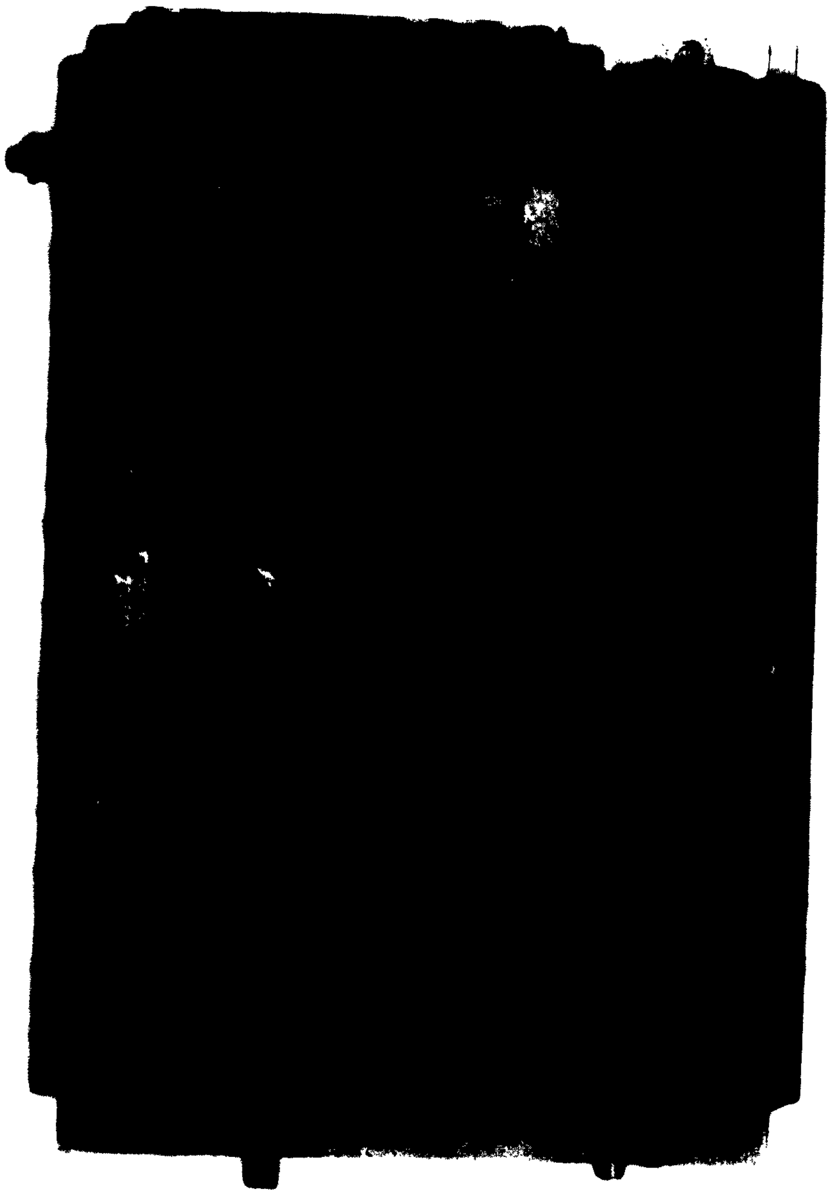


Figure 29. Four-KV Power Supply

Figure 30. Ten-KV Power Supply

1.6.3.5 **LOW VOLTAGE POWER SUPPLIES**

Transistor-regulated power supplies were selected for the reasons given in paragraph 1.1.6.3.1 for the Conditioner-Generator Unit. Specifications were written, bids were advertised, and contracts were issued for the following power-supply modules:

Volts DC	Regulation	Current	TIC Spec No.
24	±3.0%	3A	TIC 1091
45	±0.05%	1A	TIC 1089
100	±0.5%	1A	TIC 1090

The 24 volt d-c power supply can supply an output as high as 30 volts. However, by utilizing a transformer tap and a potentiometer adjustment, 24 volts dc at 3 amperes is obtained.

1.6.3.5.1 **PACKAGING** - The packaging designs for the two low-voltage power supply chassis are similar. A safety bar was incorporated in the sub-frame assembly to protect chassis-mounted components during manufacturing, handling, and maintenance.

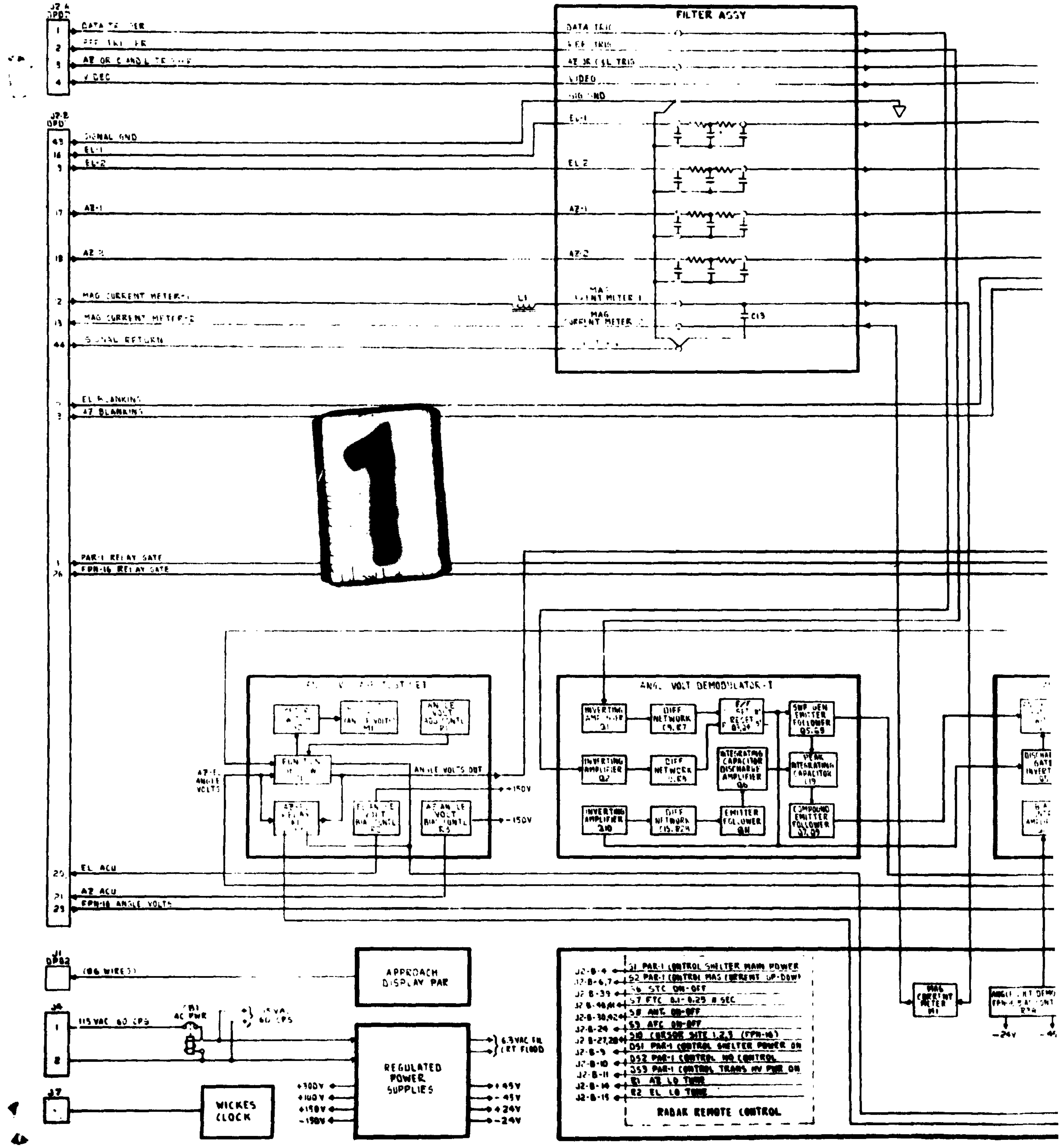
1.6.3.5.2 **OVERVOLTAGE PROTECTION** - Overvoltage protection circuits were incorporated for reasons given in 1.1.6.3.4 (Conditioner-Generator Unit).

1.6.3.5.3 **CURRENT RESERVE** - Current loads on the PAR Console low-voltage power supplies are conservative. The current reserve can accommodate additional load requirements which may become necessary due to future circuit additions.

1.6.3.6 **MECHANICAL DESIGN**

1.6.3.6.1 **SYSTEM UNIFORMITY** - Because the PAR Console is an operator's console rather than an equipment cabinet, it was not possible to maintain uniformity with the cabinets previously mentioned in the report. However, the PAR Console conforms as much as possible to other operator's consoles of the Data Processing Central.

1.6.3.6.2 **SIZE** - The primary consideration in the size of the console was the necessity to accommodate two operators sitting side by side. The overall [illegible]



FILTER ASSY
SIGNAL GND
MAG CURRENT METER-1
MAG CURRENT METER-2
EL BLANKING
AZ BLANKING
PAR-1 RELAY GATE
FPN-16 RELAY GATE
ANGLE VOLT DEMODULATOR-1
INVERTING AMPLIFIER
DIFF NETWORK
INTEGRATING CAPACITOR DISCHARGE AMPLIFIER
EMITTER FOLLOWER
PEAK INTEGRATING CAPACITOR
COMPOUND EMITTER FOLLOWER
ANGLE VOLTS OUT
EL ACU
AZ ACU
FPN-16 ANGLE VOLTS
APPROACH DISPLAY PAR
115 VAC 60 CPS
AC PWR
REGULATED POWER SUPPLIES
WICKES CLOCK
RADAR REMOTE CONTROL
MAG CURRENT METER M1

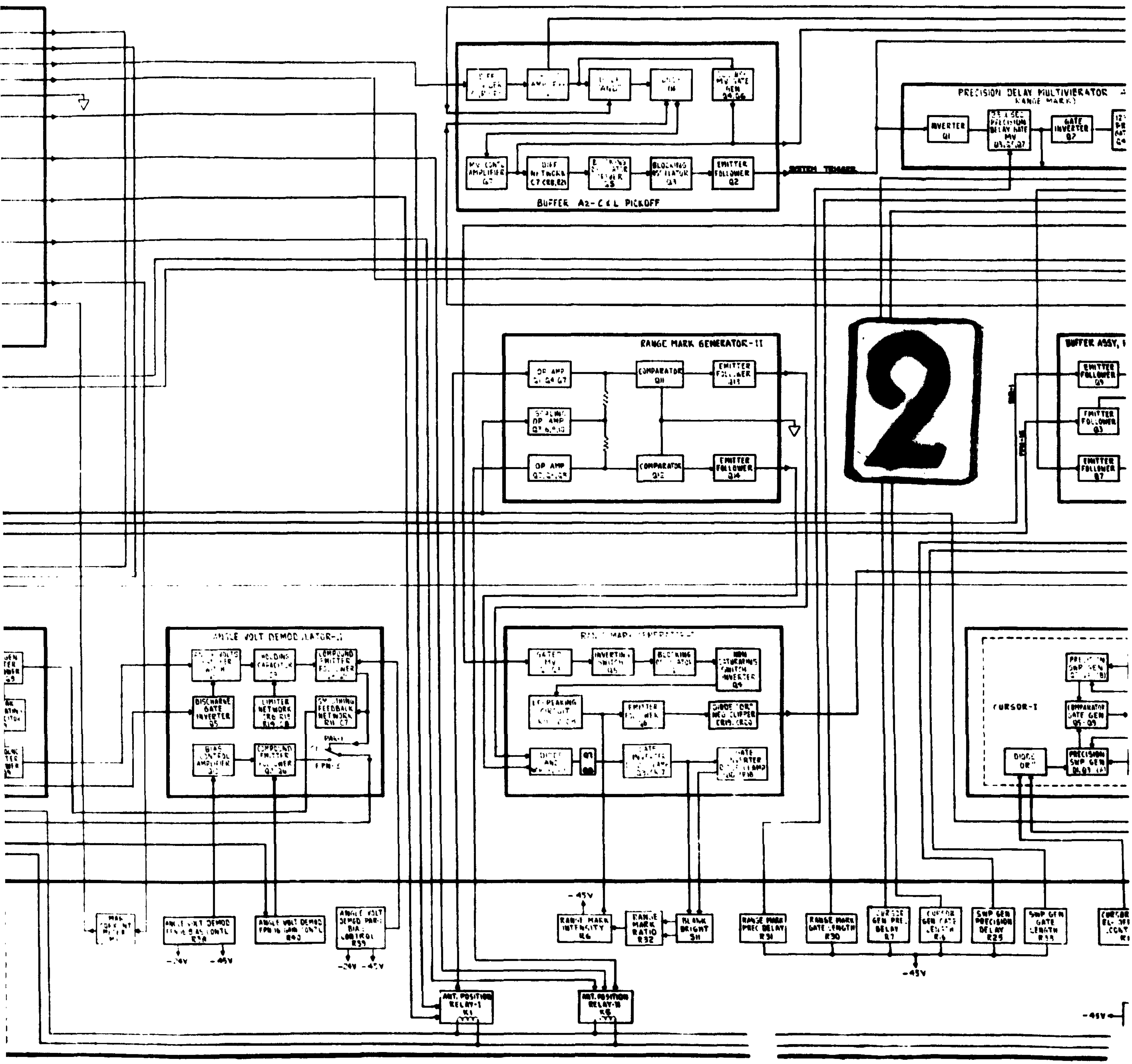
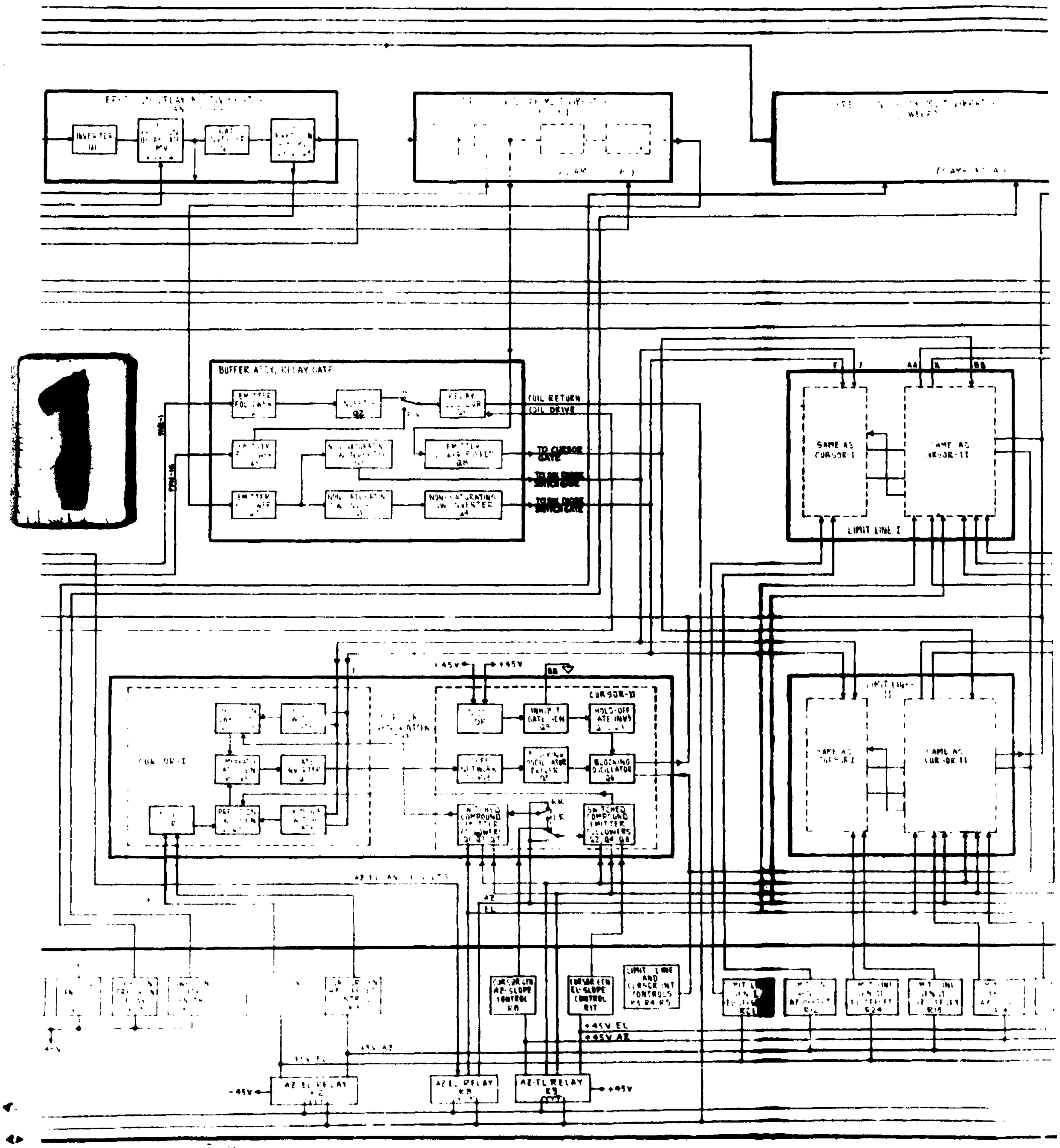


Figure 31. PAR Console, Block Diagram

Sheet 1 of 3


1
BUFFER ASSY, RELAY GATE
INVERTER Q1
COIL RETURN
COIL DRIVE
TO CURSOR GATE
NON-SATURATING INVERTER Q4
SAME AS CURSOR-I
SAME AS CURSOR-II
LIMIT LINE I
+45V
CURSOR-II
INHIBIT GATE GEN
BLOCKING OSCILLATOR
SWITCHED COMPOUND EMITTER FOLLOWERS
CURSOR CTR AZ-SLOPE CONTROL R8
CURSOR CTR EL-SLOPE CONTROL R17
LIMIT LINE AND CURSOR INT CONTROLS
+45V EL
+45V AZ
AZ-EL RELAY K3

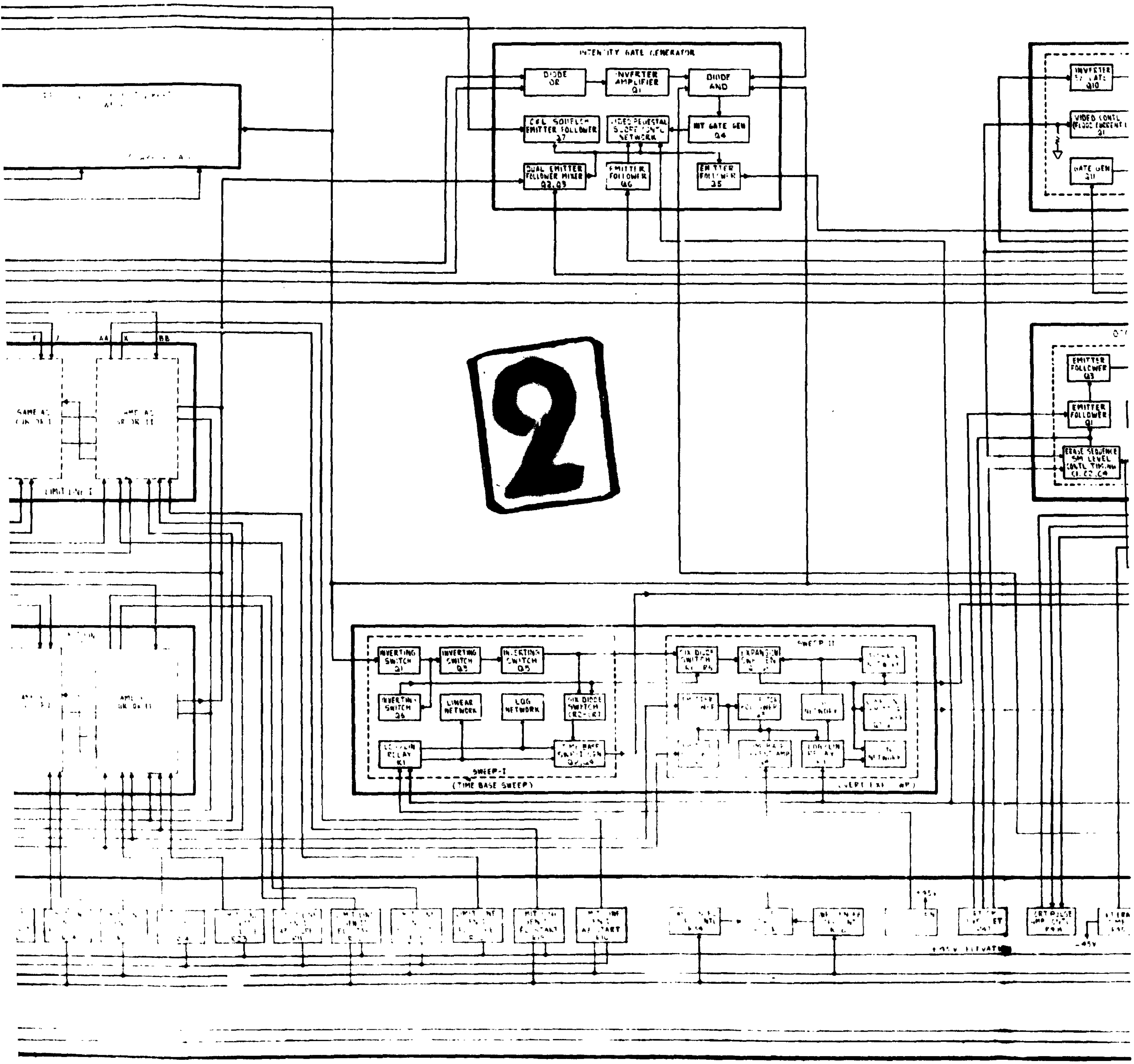
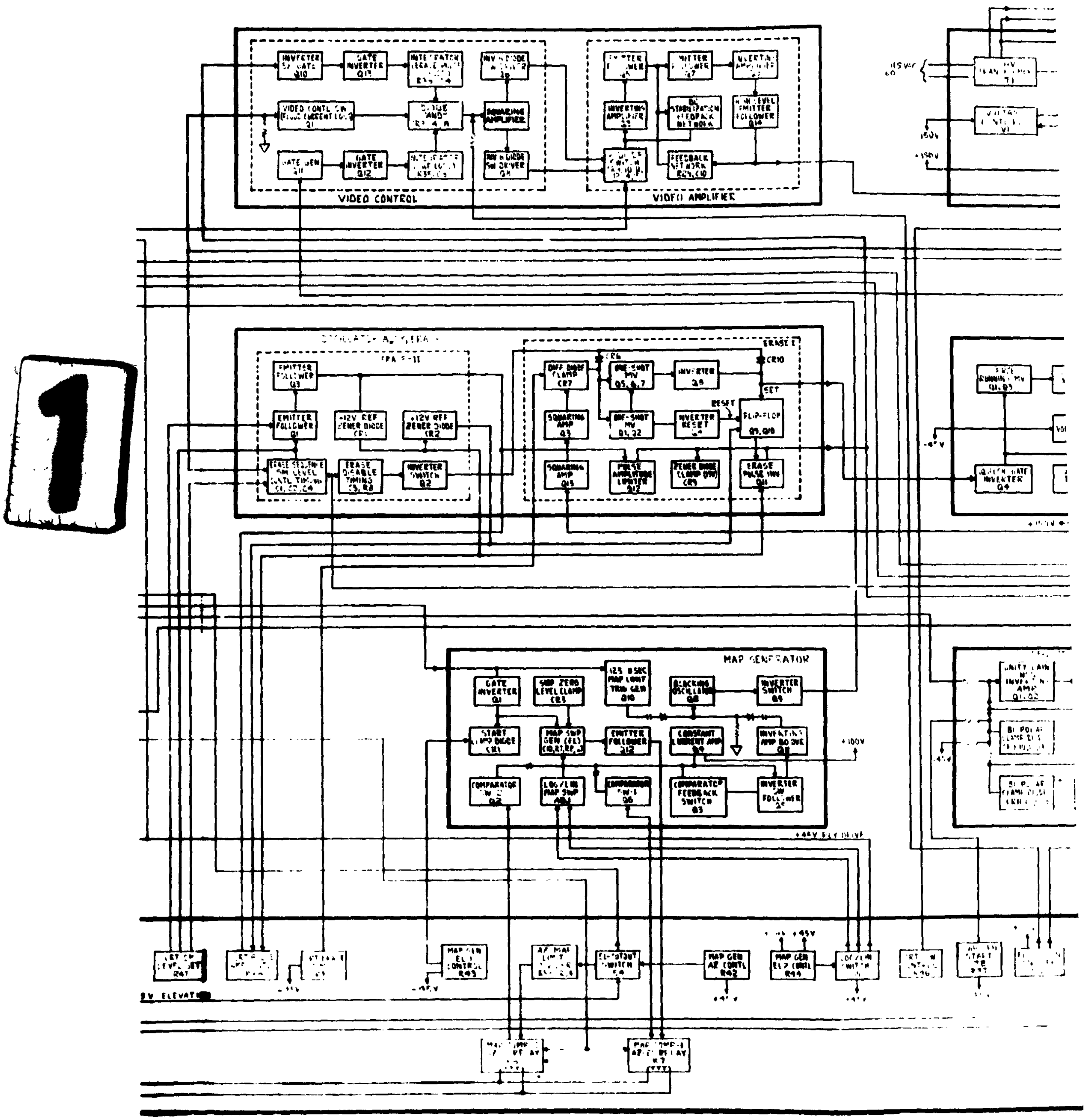


Figure 31. PAR Console, Block Diagram

Sheet 2 of 3



1
VIDEO CONTROL
VIDEO AMPLIFIER
INVERTER
GATE INVERTER Q13
VIDEO CONTL SW
SQUARING AMPLIFIER
GATE GEN
GATE INVERTER Q12
INVERTING AMPLIFIER
DC STABILIZATION FEEDBACK NETWORK
FEEDBACK NETWORK
HIGH LEVEL EMITTER FOLLOWER Q14
EMITTER FOLLOWER Q1
+12V REF ZENER DIODE
+12V REF ZENER DIODE CR2
EMITTER FOLLOWER
ERASE DISABLE TIMING
INVERTER SWITCH Q2
DIFF DIODE CLAMP CR7
ONE-SHOT MV Q5, 6, 7
INVERTER
SQUARING AMP Q3
ONE-SHOT MV Q1, 22
INVERTER RESET
FLIP-FLOP Q9, Q10
SET
RESET
SQUARING AMP
PULSE AMPLITUDE LIMITER
ZENER DIODE CLAMP
ERASE PULSE MV
CR10
ERASE
115 VAC
150V
+150V
-45V
QUENCH GATE INVERTER Q4
MAP GENERATOR
GATE INVERTER Q1
SWP ZERO LEVEL CLAMP CR3
BLOCKING OSCILLATOR Q8
INVERTER SWITCH Q9
START CLAMP DIODE CR1
MAP SWP GEN (EL)
EMITTER FOLLOWER Q12
CONSTANT CURRENT AMP Q4
INVERTING AMP DRIVE Q11
COMPARATOR
LOG/LIN MAP SWP
COMPARATOR FEEDBACK SWITCH Q3
INVERTER
+100V
+45V FLY DRIVE
UNITY GAIN INVERTING AMP Q1, Q2
MAP GEN EL CONTROL R43
EL OUTPUT SWITCH
MAP GEN AZ CONTL R42
MAP GEN EL2 CONTL R44
+45V
-45V
EV ELEVATION

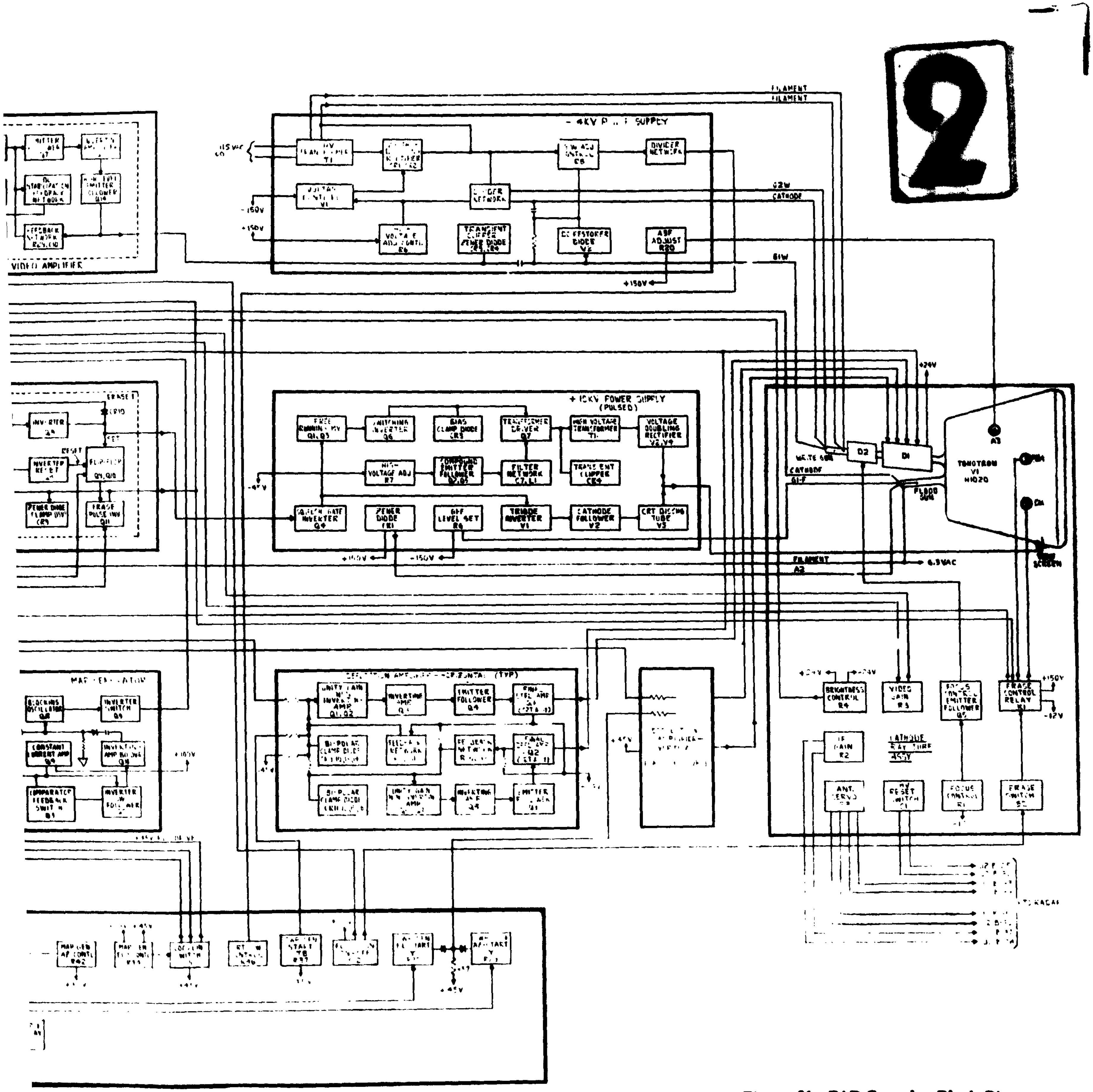


Figure 31. PAR Console, Block Diagram

Sheet 3 of 3 - 173B -

is 62 inches wide by 59 inches high by 32 inches deep, with an additional 16 inches of depth taken up by the desk.

1.6.3.6.3 STRUCTURE - The rack structure is a combination of sheet steel and structural shapes in order to achieve the maximum rigidity for mounting of heavy assemblies such as the PAR Approach Display and the CRT Indicator assembly.

1.6.3.6.4 COOLING - Cooling was not a difficult problem because power dissipation is relatively low. Two fans, which are identical to those used in the other cabinets, were employed. The air outlet has been located at the rear of the console. If the outlet were located at the top, it would be possible for personnel to impede the air flow by placing books or other material on top of the console and thus cause damage to the equipment. The air intake has been located at the bottom center front of the console.

1.6.4.6.5 CABLING - Hanger type cables are used between chassis and console connectors so that the chassis may be operated in the extended position.

1.6.3.7 MAJOR PROBLEMS AND SOLUTIONS

1.6.3.7.1 ELECTRICAL DESIGN - The termination of input signals from the PAR-1 and AN/FPN-16 radars differ, and the characteristics of the signals from these two radars also differ. In order to make the PAR Console compatible to both radars, it was necessary to incorporate a filter assembly (jumper board) in the PAR Console. Proper termination for the respective radar signals is obtained by jumpering the inputs to the correct terminals.

The deflection coil and focus coil driver transistor and current sensing resistor circuits dissipated excessive power for component board mounting. These parts were located on the CRT Indicator frame, and power was interlocked through the associated circuit cards to prevent transistor damage if the cards were removed and the power turned on. The handles of these cards were also painted red as a warning against removal of the cards while the power is on.

Turn-on of operating potentials to the crt in the wrong sequence can result in destruction of the storage surface. Also, malfunction of critical circuits could cause destruction of the storage surface. A detector circuit was utilized to sample horizontal sweep, erase pulses and flood-gun current. If any of the above are not normal, the write-gun video drive is cut off. Also, an interlock relay and front-panel located Erase button have been incorporated to interlock the flood-gun supply voltages and to provide a manual erase of the crt.

The view-screen HVPS transformer insulation and quality control was not adequate and resulted in short life of the transformer. Also, transformer failure resulted in destruction of the transformer driver transistor. The transformer quality control was improved and greater insulation provided. The peak current of the driver transistor was limited and an improved transistor selected. The Angle Voltage Test Set artificial angle voltage control was found to be too coarse for cursor generator alignment. This control was changed from a single-turn to a ten-turn control.

The protective circuits for the output transistors of the video amplifier were not adequate when arcing occurred in the negative high-voltage power supply. Better high-voltage wire was incorporated in the negative high-voltage power supply and the power dissipation of the protective circuits was increased to withstand corona arcs.

1.6.3.7.2 MECHANICAL DESIGN - The crt mounting structure, when extended, could tip over the console if all drawers were extended and pressure (180 lb.) applied to the work shelf. This problem was resolved by providing holes for placing lag screws into the floor.

1.6.3.8 ENGINEERING CHANGES

1.6.3.8.1 ELECTRICAL DESIGN - The calculated supply voltage for the deflection coil circuits was found to be marginal when generating a near logarithmic display. The deflection circuits were changed to operate using -24 volts dc as a reference, rather than ground.

1.6.3.8.2 MECHANICAL DESIGN - The GPL design which was employed in mounting the Typotron crt to the face-plate structure in the PPDD Console was originally intended for use in the PAR Console design. Calculations of the stress against the crt glass (when adding the focus coil and with the crt mounted horizontally) dictated a redesign of this structure. Also, it was found necessary to design for two crt bulb configurations. The diameter of the crt may differ in the area immediately forward of the flood gun.

The layout of the cursor generator alignment controls was found to be confusing to an operator when looking at the display and making minor adjustments. The Control Panel was redesigned and another panel fabricated as a result of this difficulty.

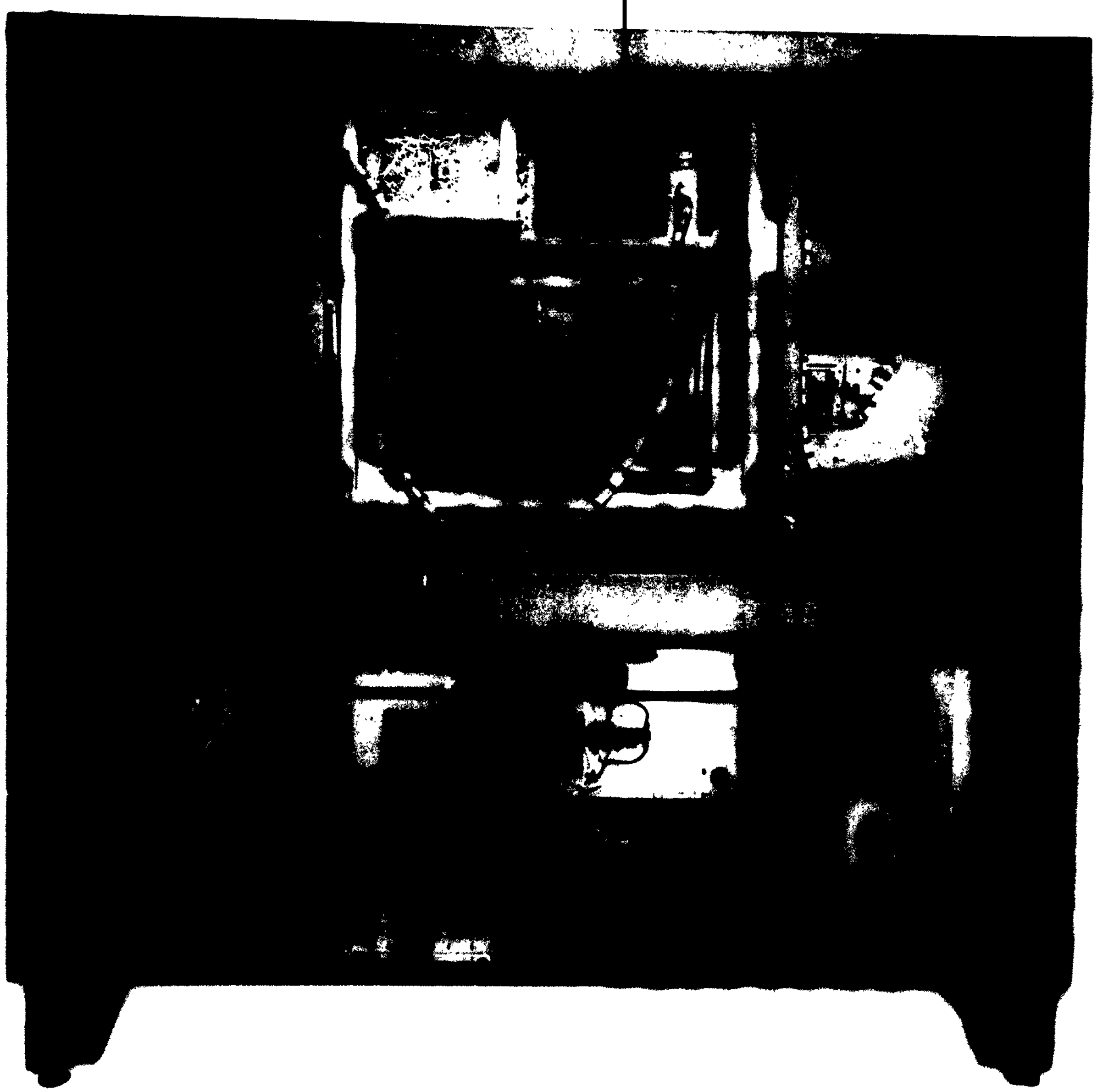


Figure 32. PAR Console, Rear View

1.6.4 RECOMMENDATIONS

1.6.4.1 SIGNAL GENERATOR - Left-of-runway or right-of-runway azimuth presentations require recalibration for each mode. A provision for a second set of calibrated controls which would permit rapid switching of left-of-runway to right-of-runway conditions may be desirable in a future modification.

1.6.4.2 CRT INDICATOR ASSEMBLY - The following changes are recommended:

1.6.4.2.1 VIEW SCREEN HVPS - The View Screen high-voltage power supply should be redesigned to provide greater peak drive power to the stepup transformer.

The stepup transformer should be redesigned to a control specification for commercial purchase.

1.6.4.2.2 NEGATIVE HVPS - The negative HVPS should be redesigned to eliminate the oil-filled filter capacitors and to provide for greater voltage gradients between components. The transformer voltage output should also be increased to provide greater range of input voltage variation without saturating the regulator circuit.

1.6.4.3 CONTROL PANEL

1.6.4.3.1 FLOOD GUN ON-OFF SWITCH - The flood gun On-Off switch should be replaced by a pushbutton switch and relay circuit, to prevent storage operation of the crt after turn on until required by the operator. This type of fall-out relay circuit will also provide added protection against crt destruction due to momentary input power failures.

1.6.4.4 LOW VOLTAGE POWER SUPPLIES - When the +24 volt and -24 volt power supplies are initially turned on (with PAR Console loads applied), the +24 volt output does not rise to the operating level. It is necessary to turn the primary power off and on again in order to attain the necessary output. This is so because of the low-impedance paths which exist between the +24 and -24 volt supplies. This condition can be corrected by modification of the power supplies.

1.6.4.5 <u>REMOTING EQUIPMENT</u> - Video restoring circuit space is available in the PAR Console to add video restoring circuits now located in the AN/FPN-16 and PAR-1 remote equipments. Also, with a modification to the present angle voltage demodulator card, the angle voltage modulator function now performed in the AN/FPN-16 remote equipment could be accomplished in the PAR Console. These changes would eliminate all remote equipments when using the PAR Console.

1.7 ANALOG COMPUTER

1.7.1 GENERAL

This portion of the report covers the development of the Analog Computer (actually a hybrid Digital and Analog Computer) until the time of its cancellation. Paragraph 1.7.1.1 explains the operations which can be accomplished by the Analog Computer in the Video Tracking System. Paragraphs 1.7.2.1 through 1.7.2.8 set forth the design objectives for the Analog Computer as a unit and for the various portions (functional blocks) of the computer. The design alternatives (paragraph 1.7.3) are also given both for the Analog Computer in general and for the sub-units and functional groups. The same approach is followed in the explanation of the principles of operation (paragraphs 1.7.4.2 through 1.7.4.2.2.5 2.8 the engineering changes (paragraphs 1.7.4.3 through 1.7.4.3.5) and the recommendations (paragraphs 1.7.5 through 1.7.5.2.4).

1.7.1.1 PURPOSE OF THE ANALOG COMPUTER

The prime contract (BRD-9) provided for the development of a large digital computer for the En Route data processing function, a second such digital machine reprogrammed for the Transition function and with program extensions applicable primarily to the Terminal Area, and, in addition, an Analog Computer (actually a hybrid Analog-digital machine) applicable primarily to the Terminal area. It was the expectation that the latter would prove a more effective solution to the terminal problem than the extended programming of the digital Transition Computer. The Analog Computer was an original requirement under BRD-318. It was subsequently terminated from the contract requirements.

The Analog Computer was intended as a high speed computer for computing certain parameters for the timing and scheduling of aircraft in the Terminal Area. The primary requirements of the computer are to compute an aircraft's actual time to fly until landing (if no controller action is taken to change it), the error in time to fly, and the scheduled position for the non-tracking mode of operation. Some secondary functions are to propose certain path-stretch maneuvers, to convert digitized aircraft position information into analog form for altitude slew, to determine optimum missed-approach landing time slots, to compute missed-approach cross positions, and to provide altitude information in digital form.

The most important information the Analog Computer produces is either one of two parameters, depending on the mode of operation (Mode A or Mode B). In Mode A operation, the Analog Computer determines the time error of the aircraft. That is, it determines the remaining time allocated for the aircraft to fly by comparing the present time to the scheduled time to land (STL) and compares the scheduled flight time to the predicted time it will take the aircraft to reach touchdown (still assuming no controller intervention). The actual time is determined

on the basis of the aircraft route, descent path, winds aloft, and the true airspeed characteristic of the aircraft in its approach. Typical true air speed (TAS) and altitude profiles are shown in figure 31, which also shows a simple route into an airport. The difference between the actual and scheduled time to fly is normally presented as error in time to fly (ETF) but in case of excessive positive error, this error, in conjunction with certain limitations described elsewhere, is used to select an appropriate path-stretch maneuver. The actual time to fly is also provided as an output.

In Mode B operation, the information is desired in a somewhat different form. In this case it is necessary to determine the coordinates that the aircraft should have if the STL is to be met. In effect, this amounts to computing present position of the aircraft and also the distance which it must travel during its error in time to fly (ETF).

In addition to the above functions, there are several minor operations that the computer must perform which contribute to the overall system operation. All of the computer operations are listed below.

The following are the primary functions of the Analog Computer:

a. To compute actual time to fly (t_f) to landing (touchdown) for a prescribed route and flight conditions from a given position, as determined by Trackers, and provide this information for printing on the electromechanical Approach Display assemblies in Mode A operation.

b. To compute scheduled time to fly (t_s) by subtracting the scheduled time of landing (STL) from real clock time (RCT), and provide this information for printing on the Approach Display assemblies and the PPDD in Mode B operation.

c. To compute error in time to fly (ETF) by subtracting t_s from t_f, as used for display on PPDD console in Mode A operation.

d. To compute scheduled position (the position an aircraft should have in order to meet its flight plan landing time schedule) as used for display on PPDD console in Mode B operation.

The following are secondary functions of the Analog Computer:

a. To devise a path-stretch pattern in order to reduce position error in ETF of the aircraft in Mode A for PPDD displays.

b. To convert digitized aircraft altitude information into analog form in order to slew a Tracker onto a target or altitude.

c. To convert digitized aircraft location information to analog information

in order to print the target circle on the PPDD in Mode B operation and to print the missed-approach cross in Mode A or Mode B.

d. To determine optimum missed-approach landing time slots as used in Mode A operation for missed-approach special display.

e. To compute missed-approach cross position for Mode A or Mode B.

f. To digitize altitude.

1.7.2 DESIGN OBJECTIVES

1.7.2.1 GENERAL

In the development of the Analog Computer, it was intended that solid state techniques be used wherever possible, in order to improve reliability, minimize dissipation, and minimize size and weight of the Analog Computer. Techniques were devised and incorporated to minimize the overall complexity of the equipment and to provide for ease of maintenance and versatility for changes during the evaluation phase of this equipment.

1.7.2.2 AIRCRAFT SIMULATOR

This section of the Analog Computer encompasses the leg resolver, route integrator and profile integrator. These constitute the major high-accuracy portions of the computer where analog functions are used. All other precision functions are accomplished digitally, thereby providing higher overall accuracy. The route integrators, the true airspeed integrator and the voltage controlled oscillator are the particularly critical items.

1.7.2.3 AIRCRAFT LOCATION DETECTOR

The aircraft simulator simulates the route path in space. In addition to this information, the aircraft coordinates are known from the Trackers. The purpose of the aircraft location detector is to determine when the simulated aircraft coordinates have reached the actual aircraft coordinates. If the aircraft were always on course, this would be a relatively simple job. However, it is necessary to make an approximation of the equivalent position in the case of an aircraft which is off course or is not exactly in the center of its route.

1.7.2.4 WIND PROCESSOR

The purpose of the wind processor is to accept as inputs, the leg angle, the wind angle and magnitude information for each of the wind levels, and the segmentized

altitude information. From this it is possible to determine the effect of the wind with respect to the route being flown. This is then combined with the true air-speed of the aircraft to provide an output of true ground speed. The relationship between these factors is derived later in this report.

1.7.2.5 ROUTE AND PROFILE STORE

The purpose of the route and profile store is to provide a means of taking the route or profile number information in combination with the segment of the route or profile being used at any instant in simulator time and from this information provide sufficient data to the flight simulator to construct a simulated route and profile.

1.7.2.6 DIGITAL PORTION OF THE ANALOG COMPUTER

The digital portion of the analog computer makes up a major portion of the computation. The functions of the digital portion are to accept the compute message from the Video Track Programmer, set up the analog portion of the computer in order to select the appropriate computation constants and computation mode, assist in the simulation by providing the timing portion of the simulation in addition to other less important functions, and finally, to accumulate the final output data to be sent back to the Video Track Programmer for storage and display. The majority of the logic and design techniques utilized in the digital portion of the analog computer were patterned after the Video Track Programmer design. The bulk of the logic cards and flip flop cards are interchangeable.

1.7.2.7 POWER SUPPLIES

The original design requirements for the Analog Computer power supplies were as follows:

Volts DC	Regulation*	Ripple	Load (ma)
-100	0.5%	0.1%	500
-45	0.5	0.1	750
-24	0.5	0.1	75
-24	3.0	1.0	500
-18	3.0	1.0	500
-12	3.0	1.0	500
+18	3.0	1.0	150
+45	1.0	0.1	750
+100	0.01	0.002	500
+100	0.01	0.002	500
+100	0.5	0.01	500

* No load to full load and ±10% of nominal input.

Additional requirements are the same as those given for the Conditioner Generator Unit (paragraphs 1.1.6.1.2 and 1.1.6.1.4 through 1.1.6.1.9).

1.7.2.8 ANALOG COMPUTER CABINET

Design objectives for the Analog Computer cabinet were the same as for the Conditioner-Generator Unit (paragraphs 1.1.7 through 1.1.7.1.6).

1.7.3 DESIGN ALTERNATIVES

1.7.3.1 DESIGN ALTERNATIVES FOR ANALOG COMPUTER IN GENERAL

1.7.3.1.1 NETWORK APPROACH

The original technique considered for instrumentation of the Analog Computer, was the use of fixed, active, electronic networks to generate the answers to the problem directly upon selection of appropriate networks and application of appropriate input signals. This technique had serious limitations in flexibility and in the degree of likeness that the equipment could simulate the real-world situation.

1.7.3.1.2 SIMULATION TECHNIQUE

The simulation technique simulates the real-world situation on an analog scale to determine the required outputs. The initial simulation technique considered is shown in figure 34. Simulation essentially added the capability of using time as a variable. By using time, it was possible to more realistically reproduce the real-world situation.

In this technique, the parameters of the real situation are simulated by providing certain electrical analogs of physical parameters. These electrical analogs might be voltage or current in the case of inputs and similar functions. They can be switched in resistive networks to simulate the variety of routes and profiles. In the initial simulation technique, voltage analogs were used extensively.

Upon further consideration, it was determined that the simultaneous use of analog and digital techniques could provide increased accuracy in critical areas, simplify the equipment, and improve reliability.

The first item considered for digital simulation was the method of keeping track of time. The simulation technique essentially generated an artificial aircraft which would perform in a manner identical to the physical aircraft in flight. In this sense, position is described as the integral of velocity and the independent variable is the distance from touchdown. It is possible to build networks that will describe the route geometry as a function of this distance from touchdown

and, in turn, this route geometry can be compared to the actual position of the physical aircraft. Taking into account aircraft velocity and wind velocity, a time to fly for the aircraft can be determined. Meanwhile, the scheduled time that the aircraft has left to fly, knowing the present clock time and the scheduled time to land of the aircraft, can be determined by essentially running down a clock at the simulator time rate or by generating a ramp voltage analog of time. By this means, a determination of the actual time to fly of the aircraft can be made and this time can be compared to the scheduled time to fly in order to determine the error in time to fly. This had a major advantage in requiring very little difference between Mode A and Mode B equipments. With this approach, the Mode B coordinates are essentially the coordinates of the simulator provided by the route generator output at the scheduled time to fly.

1.7.3.1.3 USE OF ETA IN PLACE OF LS NUMBER

When the simulation technique was first considered, it was planned to make use of the landing sequence numbers and the spacing between successive aircraft to compute the scheduled time to fly of the aircraft. The number of landing sequence numbers between the touchdown point and the aircraft multiplied by the spacing time is the time to fly remaining for the aircraft.

1.7.3.1.4 TRACKER EDUCATION

Tracker education makes use of the route knowledge stored in the Analog Computer in order to increase the tracking accuracy and tracking capabilities of the Tracker. The subject would cover any method wherein the route information would be used to provide additional data inputs in some form to the Trackers. It should be possible to achieve higher tracking accuracies in situations involving low speed radars or high speed aircraft. The Trackers could thus be made to track more accurately at corners where the Tracker normally picks up its greatest errors.

One approach is to use the Analog Computer velocity information directly in the Trackers. In this case, the Trackers will make use of the combination of computer stored airspeed information and route information in order to derive the velocities for the Trackers. This would result in a simplified Tracker that would merely update position upon each radar hit. The only way that radar information would be utilized in such a plan would be in updating position. This would work fairly well for an aircraft that is flying close to the assigned routes and flying close to its proper speed. However, this technique would not work at all in the case of an aircraft which suddenly changes course to some non-predetermined direction.

A compromise approach might be to make use of the normal memory (velocity memory) information of the Tracker and add with this velocity information a fraction of the velocity from the Analog Computer. This would tend to alleviate

the problem of complete domination by the stored information.

A second technique which holds promise is to make use of acceleration information from the Analog Computer. In this case the acceleration, particularly at corners, would be fed into the Tracker as additional data in order to start the Tracker around the corner at the appropriate time. This might be done on the basis that the Analog Computer would provide no information until a large acceleration along one of the axes was required. Then this acceleration information would be fed directly to the Tracker in order to make it follow the Analog Computer immediately. This should reduce the difficulty of tracking at corners.

A third approach to flight-plan tracking is to either use route information only, or to make less use of the stored speed information. The Analog Computer can determine where the aircraft should be ideally, let us say one minute from now. Therefore, the computer could effectively provide a hit at the route position where the aircraft should be one minute from now, and this hit could then be used in combination with the position information stored in the Tracker in order to provide velocity information and acceleration information which would set the Tracker on a course to pass through this point. By maintaining this point some distance ahead of the aircraft, it would be possible to achieve satisfactory results in tracking the aircraft around corners and yet not dominate the Tracker.

1.7.3.1.5 FUNCTION GENERATOR

In order to generate arbitrary functions of a voltage variable, it is necessary to develop a network that is capable of generating an arbitrary output function of some input voltage variable. Several standard function generator techniques were considered. Some of these techniques were breadboarded and tested.

1.7.3.1.6 DIGITAL TO ANALOG CONVERSION TECHNIQUES

The first Digital to Analog Converter technique tested was one which employed voltage switching and required elaborate temperature compensation techniques. In view of the complexity of this method, further techniques were investigated and the final digital to analog conversion technique used was one employing current-mode switching at the virtual ground point or the input point of a high-gain operational amplifier with operational feedback. By using a very high voltage (100 volts), it was necessary to consider compensation only for the major digits. This compensation was relatively simple to perform.

1.7.3.1.7 CHANGE OF TIME-DEPENDENT VARIABLE

In the development of the simulation approach to the computer, the first technique to be considered was the use of the voltage analog of distance from

touchdown, and a time analog of time or a proportional fast time base. However, in the early part of 1960, work on the computer was being resumed after a dormant period and consideration was given to other techniques, particularly methods of eliminating the very large number of potentiometers required and their questionable reliability. It was then decided that it would be best to deviate from this voltage analog of distance and time analog of time by a change that did not seriously affect the portions of the computer on which a significant amount of design time had been spent. This technique was to use a time analog of distance to touchdown. That is, distance from touchdown was to be made proportional to real time and a variable clock rate was to simulate time itself. The clock for the time accumulation section of the Analog Computer was to be designed so that the time between clock pulses would be directly proportional to ground speed. Therefore, at the point at which the simulated aircraft meets the Tracker position in simulation, the number of clock pulses that have occurred from the start of simulation to the meeting point would provide an indication of the time from touchdown to the meeting point.

This would seem to be a change in the basic philosophy of the computer. However, the hardware is not significantly affected except in certain areas where there was a serious reliability question.

The change in time-dependent variables was closely related to studies made on the reliability of the network methods of route and profile constants storage. The first storage techniques which were considered involved arbitrary function generators with potentiometers to allow these networks to generate any route or profile function. This approach required thousands of potentiometers and, to restrict size within reasonable proportions, it was necessary that the potentiometers be miniaturized. An evaluation of commercially available potentiometers with the required characteristics showed that reliability under high-accuracy conditions would be poor.

1.7.3.1.8 WIND UPDATE TECHNIQUE

One of the problems in the operation of the Analog Computer is that when new wind data is received from the Weather Bureau, aircraft in the affected area would suddenly appear to have large errors if this new wind data is set in immediately, since it would appear to the Analog Computer that these aircraft have acquired a new speed. The error would be in proportion to the wind change. Therefore, in order to minimize the transient effect of setting in the new meteorological wind, the wind is set in to the new value at a slow rate. That is, the wind is changed from the old value to the new value quite slowly.

Several techniques for doing this were considered. One of the earliest techniques considered was to use a mechanical arrangement whereby a knob would be adjusted from the old value to the new value. This would, in turn, start a timing motor which would very slowly turn the wind set-in potentiometers from the old

setting to the new setting. This design was considered rather seriously and some initial layout progressed along this line.

Further studies were instigated since these systems appeared to be fairly expensive. The final technique was to compare the value which was to be set in (stored on digital thumbwheels) to the potentiometer active store in analog form and, on the basis of the comparison, update the active wind stores. These active stores are driven by small d-c motors If there is a difference between the desired value and the setting, a motor will be pulsed in the appropriate direction to correct the wind data. One of the advantages of this technique is that it now becomes possible to take into account the average aircraft speed error which presumably could be caused by wind.

1.7.3.1.9 WIRE LIST PHILOSOPHY

The design of the Analog Computer required a combined design of analog sections and digital sections. In the development work on the Video Track Programmers, certain techniques were devised for cataloging and simplifying the wire lists, and attempts were made to simplify the cabling. In the Analog Computer it was desirable to employ a similar pattern. The digital portion was described by logical equations and these logical equations were broken down by using punch-card tabulating equipment. In addition to this, each wire in the computer was given an individual code name. These code names were then made available for cross reference as to chassis, signals, and exact destination in the equipment. This technique allows the wire lists to be placed on punched cards so that the cabling information for the rack or any chassis can be determined very quickly by means of a card sort. In addition to this, the information can be cross correlated in order to obtain lists of signals at a particular connector and similar information.

1.7.3.2 DESIGN ALTERNATIVES, DETAILED

1.7.3.2.1 AIRCRAFT SIMULATOR DESIGN ALTERNATIVES

As an alternative to the use of the analog sine-cosine generator or resolver and the use of analog integrators, it would have been possible to do this portion of the job in the manner of a digital differential analyzer using registers and parallel adders to provide the integrating functions and to provide the sine and cosine of the leg angle.

The first technique considered for the voltage controlled oscillator was to use a simple multivibrator circuit with temperature stabilization. However, upon review of this circuit, it was decided that it would be better to investigate other techniques and eventually a technique involving an operational amplifier as an integrator and comparator was selected. This technique provided sufficient accuracy.

The altitude segmentizer makes use of a modification of the function generators to provide discrete segmentized outputs. Earlier techniques for doing this consisted of rather critical pulse sensing methods and use of comparators which were not nearly so accurate.

1. 7. 3. 2. 2 AIRCRAFT LOCATION DETECTOR DESIGN ALTERNATIVES

1. 7. 3. 2. 2. 1 SIMPLE LOCATOR - One of the first systems considered for the aircraft location detector was to merely look for either coincidence in the North-South coordinates or coincidence in the East-West coordinates. It is also possible to discriminate as to whether the route heading is more nearly East-West. The disadvantage of this approach is that the off-course approximation is only good when the aircraft is either going due North-South or due East-West. The maximum error point is at 45 degrees and the error in forward distance is equivalent to .707 times the off-course distance. One of the better approximations to the equivalent location is to estimate that the aircraft that is off course is at an equivalent distance from touchdown as is an aircraft that is at the foot of the perpendicular from the route to the aircraft. This is particularly well adapted when the aircraft is not near a corner. However, an aircraft in a corner presents a rather serious problem; and even taking into account velocities and going into very involved schemes, there is no ideal solution to this problem unless there is some way for the Analog Computer to know exactly in which direction an aircraft will take from a certain position.

Another technique considered was to effectively use a perpendicular modulation signal to the route path. This would be done by causing a superimposed modulation on the x and y route coordinates generated by the route generator. In order to make the modulation perpendicular, the relative components of the modulation would have to be assigned a magnitude which is determined by the sine and cosine of the leg angle. Consideration of this method showed that the design problems involved and the hardware required would be more complicated than the technique employed in the final aircraft location detector (paragraph 1. 7. 4. 2. 2. 2).

1. 7. 3. 2. 2. 2 CORNER TECHNIQUES - The aircraft location detector, as designed for the Analog Computer, effectively determines when a line between the aircraft and the simulated aircraft is perpendicular to the route angle. For an aircraft in a corner region, it can be seen that if a right angle corner is used, the aircraft might be lost in the corner. An easy way to see this is to draw a line perpendicular to the route at all points. In a right angle corner, there is a region on the outside of the corner which is completely missed. In order to avoid this problem, corner rounding was used in the angle generation. The aircraft location detector makes use of the route leg angle. This leg angle information, in the latest thinking and before the computer was terminated, was to be taken as identical to the angle used for route generation. However, this need not be done, as very good approximations can be achieved by using a different source of leg

angle information for the aircraft location detector. In this case, the route generator would use leg angles with either no rounding or very little rounding or perhaps with a rounding which is proportional to the aircraft velocity, whereas the aircraft location detector would make use of very grossly rounded corner data.

1.7.3.2.3 WIND PROCESSOR DESIGN ALTERNATIVES

1.7.3.2.3.1 IGNORING OF CRAB ANGLE - A significant simplification of the wind processor assembly can be made by ignoring crab angle. If there is a cross-wind, then the ground speed will be slower than the TAS, since the heading angle and course angle are not the same. If this is ignored, the wind equation to be solved is simply that the wind component of the speed is the magnitude of wind times the cosine of the angle between the wind and the leg.

1.7.3.2.3.2 WIND SET-IN MECHANISMS - It is possible to devise many alternate techniques for slowing down the wind entry. As described in 1.7.3.1.8, it is necessary to slow down the entry of the wind data so that severe transients will not affect the system. The final wind set-in technique uses simple mechanical equipment and time-shared electronic equipment. One approach which was thoroughly evaluated made use of a timing motor driving a mechanical interlock arrangement so that when the knob on the front panel was turned, a follow-up mechanism slowly approached the setting of the front panel knob, until they were equal, and the mechanism shut off the motor.

1.7.3.2.4 ROUTE AND PROFILE STORE DESIGN ALTERNATIVES

1.7.3.2.4.1 FUNCTION GENERATOR NETWORKS - The first technique considered for storage of route and profile information was to make use of function generator networks, that is, generate the North-South and East-West coordinates as functions of distance from touchdown and to build up the profiles by means of non-linear diode function generators.

1.7.3.2.4.2 SWITCHES - The final technique made use of semi-fixed digital storage. Establishing of this semi-fixed digital storage could be done in several ways. One method considered was to simply use switches. This would use a switch storage technique somewhat similar to the wind updating system described earlier. However, the routes and profiles would not be updated as frequently as the wind information. Therefore, the extreme flexibility of switches is not needed and other techniques were found to be less costly.

1.7.3.2.5 DIGITAL PORTION, DESIGN ALTERNATIVES

1.7.3.2.5.1 **SPECIALIZED LOGIC** - One of the decisions that had to be made in the construction of the digital portion of the Analog Computer was whether to make use of special-purpose logic cards or to take advantage of the already designed general-purpose cards developed for the Video Track Programmer. On analysis, it was determined that the general-purpose cards would result in fewer debugging problems and lower overall costs for a one-shot item such as the Analog Computer. Therefore, the decision was made to use general-purpose logic. However, in certain applications and interface areas, it was necessary to make use of specialized logic techniques. Also it was found that some simplifications could be made with the specialized logic which proved to be satisfactory, but in general this practice was avoided.

1.7.3.2.5.2 PUNCHED CARD DESIGN

In the course of the work on the Video Track Programmer, some consideration was given to the possibility of simplifying the task by taking advantage of punched card techniques. In the Analog Computer, it was decided to go ahead with this approach and a significant amount of work was eliminated by using punched-card techniques to aid in the reduction of logic and in the final determination of the card types required for the final design of the digital portion of the Analog Computer.

1.7.3.2.6 POWER SUPPLY DESIGN ALTERNATIVES

Design alternatives for the Analog Computer power supplies were the same as for the Conditioner-Generator Unit power supplies (paragraph 1.1.6.2).

1.7.3.2.7 ANALOG COMPUTER CABINET DESIGN ALTERNATIVES

The design alternatives for the Analog Computer cabinet were basically the same as for the Conditioner-Generator Unit (paragraphs 1.1.7.2 through 1.1.7.2.4).

1.7.4 FINAL DESIGN

1.7.4.1 DISPOSITION OF DESIGN ALTERNATIVES

1.7.4.1.1 NETWORK APPROACH - Because of the limitations in flexibility and difficulty in simulating the real-world situation, this technique was discarded and the simulation technique described in paragraph 1.7.3.1.2 was employed.

1.7.4.1.2 SIMULATION TECHNIQUE - The simulation technique described in paragraph 1.7.3.1.2 was adopted because it accomplished both Mode A and Mode B operation with the smallest amount of hardware and the least degree of complexity.

1.7.4.1.3 USE OF ETA IN PLACE OF LS NUMBER - A major disadvantage of this alternative was that the computer must know when the transition controller has determined that the spacing should be changed. It was therefore decided to have the controller enter the ETA into the Video Track Programmer. By this means, the difference between the ETA and present time is provided as the scheduled time to fly for the aircraft.

1.7.4.1.4 TRACKER EDUCATION - It was determined that it would not be feasible to include such techniques in the present design. However, it may be desirable to evaluate this technique at the testing site.

1.7.4.1.5 FUNCTION GENERATOR - It was very difficult to determine the exact parameter values for the function desired, and the circuits tended to lack accuracy. Therefore, a new function generator technique was devised which improved accuracy to the degree necessary and allowed for very simple determination of network parameters. The final function generator technique involves a non-linear network in the feedback loop of a high-gain operational amplifier. By this means, inaccuracy effects of the silicon diodes are greatly reduced.

1.7.4.1.6 DIGITAL TO ANALOG CONVERSION - The digital-to-analog conversion technique employed in the Digital to Analog Converter (paragraph 1.1.4.3.2) was selected for use in the Analog Computer. The Analog Computer conversion circuits are very similar except that high-voltage power supplies were employed.

1.7.4.1.7 **CHANGE IN TIME-DEPENDENT VARIABLE** - The technique of using a time analog of distance to touchdown was adopted in preference to using voltage analog of distance and time analog of time. This decision eliminated the large number of potentiometers and the accuracy and reliability problems associated with the use of potentiometers.

The change of variable permitted a new and unique solution to the time-dependent variable problem. Since the routes and profiles are functions of D_g (distance to go), it became possible to generate these functions by integration of fixed constants.

1.7.4.1.8 **WIND UPDATE TECHNIQUE** - The technique of updating wind on the basis of analog comparison, as described in paragraph 1.7.3.1.8, was selected.

1.7.4.1.9 **WIRE LIST PHILOSOPHY** - It was recognized that operation of analog and digital circuits in close physical proximity would pose serious noise problems. A great deal of caution was therefore exercised in routing of power-supply outputs and ground returns. This results in several wires which carry the same d-c voltage and several ground wires in a single chassis. The wire list philosophy described in paragraph 1.7.3.1.9 was therefore selected as the only feasible method of tabulating wires within the Analog Computer.

1.7.4.1.10 **AIRCRAFT SIMULATOR** - The digital techniques were not used in this design because of their greater expense and because it appeared that the required accuracies could be achieved without the expense of the numerous registers and the large amount of logic required in the pure digital approach.

1.7.4.1.11 **AIRCRAFT LOCATION DETECTOR** - The basic concept of the simple locator (paragraph 1.7.3.2.2.1) was employed. The final design utilizes a method of counting pulses during a "backward flight" of a simulated aircraft from the touchdown point to the point of coincidence with the real aircraft. The method is described in detail in paragraph 1.7.4.2.2.2.

1.7.4.1.12 **WIND PROCESSOR** - The method described in paragraph 1.7.3.2.3.1 was employed. The final design is described in detail in paragraph 1.7.4.2.2.3.

1.7.4.1.13 **ROUTE AND PROFILE STORE** - The technique of using function generator networks was rejected because of the requirement for several hundred potentiometer adjustments. The final design incorporates semi-permanent digital

storage as described in paragraph 1. 7. 4. 2. 2. 4.

1. 7. 4. 1. 14 DIGITAL PORTION - General-purpose logic was selected to achieve minimum cost and the shortest lead time for a one-shot item such as the Analog Computer. The punched-card design was selected to provide for a minimum effort expended on logic reduction and to provide the capability of having multi-purpose function lists and other aids to the trouble-shooting portion of the development.

1. 7. 4. 1. 15 POWER SUPPLIES - The final selection of operating potentials and the resultant power-supply assemblies and modules are described in paragraph 1. 7. 4. 2. 6.

1. 7. 4. 1. 16 ANALOG COMPUTER CABINET - As previously noted, the design alternatives for the Analog Computer cabinet were basically the same as for the Conditioner-Generator Unit. Accordingly, the same final choice was made with one exception as noted below. A standard, commercially available rack structure was utilized, the dimensions being 77-1/8 inches high by 34-9/16 inches wide by 25-1/2 inches deep. The width was established in accordance with the dimensions of the chassis previously described in order to allow one horizontal row to accommodate two plug-in card chassis and one power-supply chassis. The several small power-supply chassis are each mounted between two printed-circuit card chassis.

Vertical panels were incorporated to direct cooling upward in 3 vertical columns. A rear vertical panel was included for mounting connector plates. Parts such as the rear connector plates were standardized to reduce production costs. A connector panel was incorporated at the bottom of the cabinet for inter-connection with other cabinets.

A rear hinged door was incorporated to provide access to cabling at the rear of the connector plates. No front door was provided, since the front panels of some of the chassis contain test points.

The rack was modified slightly to accommodate a special chassis for selection of route and profile patterns. This chassis was designed as an assembly of solderless pin connector blocks with coordinates labelled for ease of coding. It was designed to be mounted permanently on a modified rear door and to be connected to the remainder of the cabinet by means of an umbilical cable.

Because of the special chassis described above, the depth of the cabinet was made 28-1/2 inches. The added depth was provided by means of a skirt attached to the rack. A hinged door is mounted on the skirt.

1.7.4.2 ANALOG COMPUTER PRINCIPLES OF OPERATION

1.7.4.2.1 GENERAL

Figure 33 is a generalized block diagram that can be used to describe nearly any data processing system. The titles in parenthesis indicate the units in the data processing equipment built by Tasker (except for the TDPG and displays) which correspond to the general block diagram. The function of the Analog Computer is essentially to serve as a special-purpose high-speed arithmetic unit in this system. Figure 49 is a block diagram of the digital portion of the Analog Computer. Figures 36, 37 and 47 are block diagrams of analog portions.

Table 2 lists the operations performed by the Analog Computer. The most important operations performed are No. 1 through No. 4.

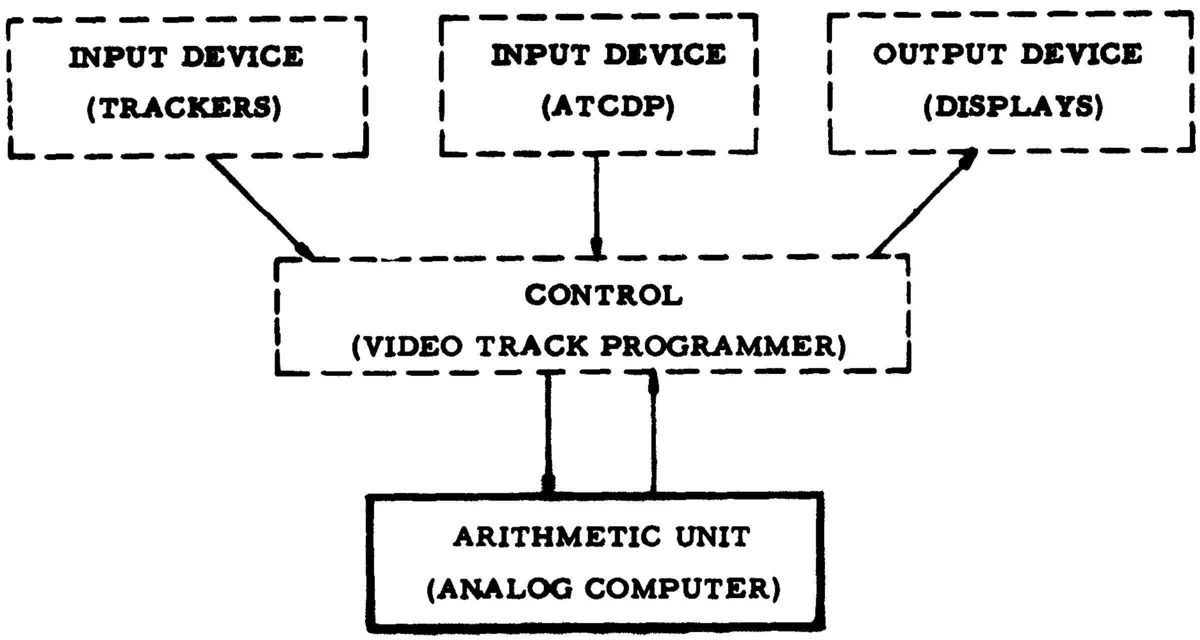


Figure 33 Generalized Data Processing System

TABLE 2. ANALOG COMPUTER OPERATIONS

MODE A ONLY

1. Compute error in time to fly or path-stretch instruction.
2. Compute time to fly (actual) for presentation on Approach Display.

MODE B ONLY

3. Compute scheduled position coordinate for circle display on PPDD.
4. Compute time to fly (scheduled) for presentation on Approach Display.
5. Convert scheduled position to digital form for storage until print cycle and convert from digital to analog during print.

MODE A AND MODE B

6. Determine optimum missed-approach landing time slot for missed-approach special display.
7. Compute empty time-box cross coordinates on missed-approach routes and store as in (6).
8. Convert 3-D Tracker altitude information to digital form for display in character format.
9. Convert digital altitude to analog form for Tracker slew.

Table 3 lists the primary inputs and outputs of the Analog Computer. It should be noted that the D to the left of the number indicates that this information is provided in digital form and the A indicates that the input or output is in analog form. With the inputs and outputs shown, the Analog Computer is able to perform the operations indicated in Table 2.

Figure 34 helps to show how the major operations are performed by simulation. The route in this figure is shown with an aircraft approaching touchdown. The simulator simulates an aircraft flying backwards from touchdown until it intercepts the actual aircraft. This simulation provides voltage coordinates in the same scale as the Tracker coordinates, so that these coordinates can be compared to determine when the simulated aircraft has reached the actual aircraft. The small oval shown indicates what is called scheduled position. This scheduled position is determined by a point in space where the aircraft should be if it is to make good its scheduled time to land. Time marks are also shown on this diagram. These represent uniform time points to touchdown. That is, the spaces between the time marks represent uniform intervals of time.

From this information, we can determine the relations required. First of all, the distance between the time marks is directly proportional to the true ground speed of the aircraft. This is readily seen for an aircraft at constant velocity. If the velocity is constant, distance is merely the velocity times the time. For changing velocities, this can be done on a smooth or fine-grained incremental basis. The total number of time marks which occur between touchdown and the actual aircraft position for the simulator (going backwards) is equal to the actual time to fly (t_f). Also, the scheduled time to land minus the present time (the difference between time at which the aircraft should land and present time) is the scheduled time the aircraft has left to fly. The scheduled time to fly can be represented as so many time marks. Figure 34 shows that the scheduled time to land is the summation of time marks between touchdown and the scheduled position. This particular information used is in determining the scheduled position of the aircraft. The position of the simulated aircraft at the time when all of the time marks are used up corresponds to the scheduled position of the aircraft. Another relation that is needed is the difference between the scheduled time to fly and the actual time to fly. This difference is the error in time to fly, which is one of the desired outputs. Most of the above functions are derived by means of aircraft flight simulation. Upon receiving a proper signal from the Video Track Programmer (VTP), the Analog Computer performs a simulated flight (and computation) on an aircraft. The VTP causes a simulated flight to occur for up to 50 aircraft within less than three seconds.

During a simulated flight in the Analog Computer, the simulated aircraft begins at touchdown on the runway and flies backward to the actual position of the real aircraft as determined by the Tracker assigned to the aircraft. The simulated flight uses the same route and altitude profile that the actual aircraft would fly in a forward direction. Of course, the simulated flight is performed in fast time. Less than 35 milliseconds is required to complete the simulated flight.

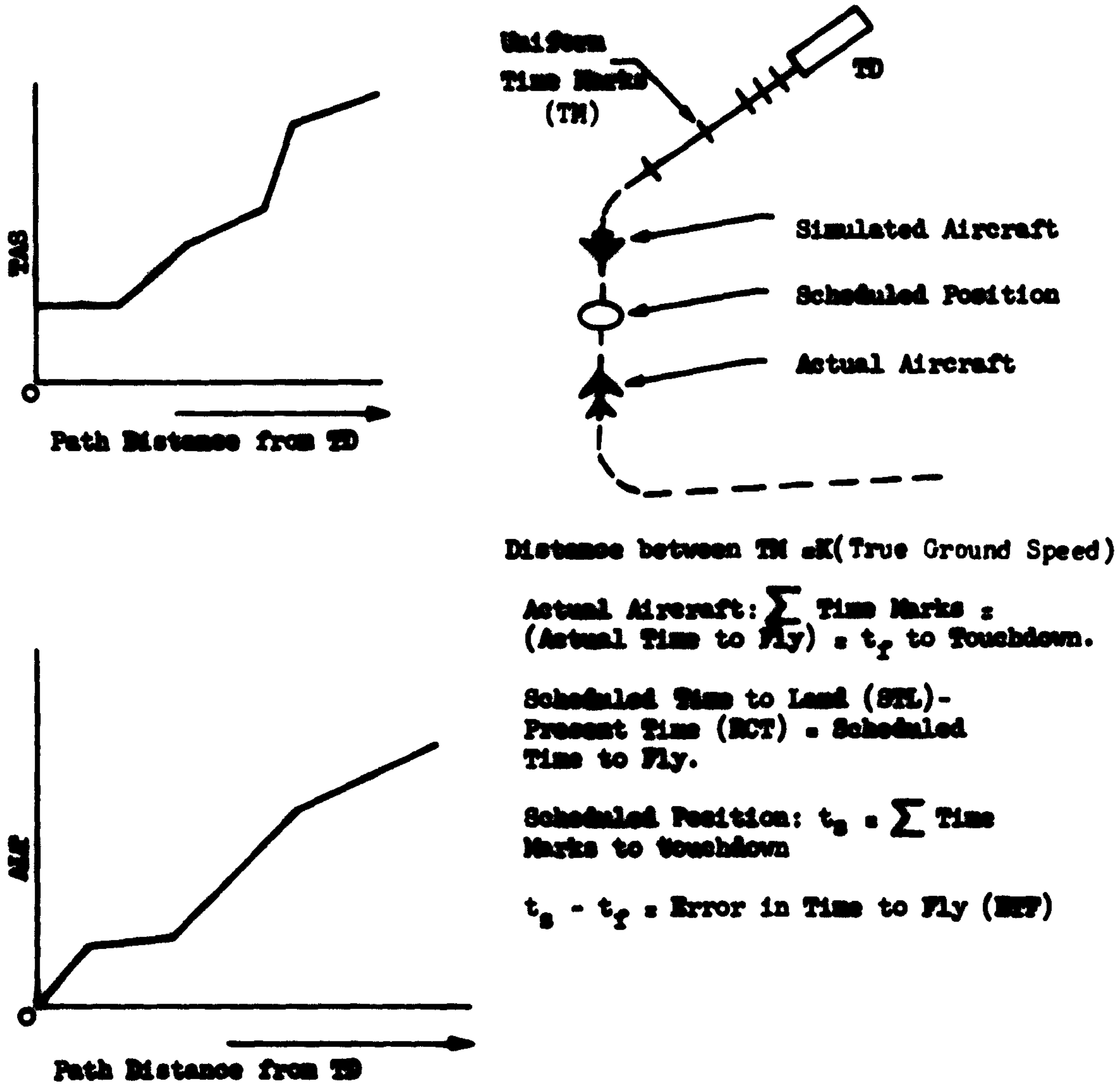


Figure 34. Flight Simulation

TABLE 3. ANALOG COMPUTER INPUTS AND OUTPUTS

INPUTS

* D	1.	Profile No. (selects internally stored TAS versus distance and altitude versus distance profiles).
D	2.	Route No. (selects internally stored route constants).
D	3.	Scheduled time to land.
**A	4.	Tracker coordinates
D	5.	Scheduled coordinates (for incoming aircraft).
D	6.	Digital altitude (altitude slew).
D	7.	Error in time to fly (for rounding off).

OUTPUTS

D	1.	Display Error (ETF or path-stretch indication).
DA	2.	Time to fly
D	3.	Schedule coordinates (for display)
D	4.	Altitude (with 3-D tracking)
A	5.	Leader offset (mode B circle print).
A	6.	Cross coordinates (cross print).
A	7.	Altitude (altitude slew).

NOTE: * D = Digital
**A = Analog

1.7.4.2.1.1 AIRCRAFT SIMULATOR

The Aircraft Flight Simulator utilizes an analog aircraft simulation technique in association with digital timing techniques. The quantities that must be known about the aircraft in order to derive the necessary information are as follows:

The first of the required quantities is the aircraft profile. This is the altitude path the aircraft will take in space and the true air speed (TAS) which the aircraft will have at each point along the path. Nearly all functions are basically related to distance to go (D_g). The altitude profile and speed profile are given in the form of altitude versus distance and speed versus distance curves (see figure 35). The second major quantity that must be known about the aircraft is the route the aircraft will take. There are a number of routes by which aircraft can enter into the terminal area and approach the landing field. However, in order to make an accurate computation on an aircraft, the route which the aircraft will take must be very accurately known. The route itself can be simulated by instrumenting the parametric equation $X = f(D_g)$ and $Y = (D_g)$. Setting up arbitrary functions of this nature allows any arbitrary projected path in space to be generated.

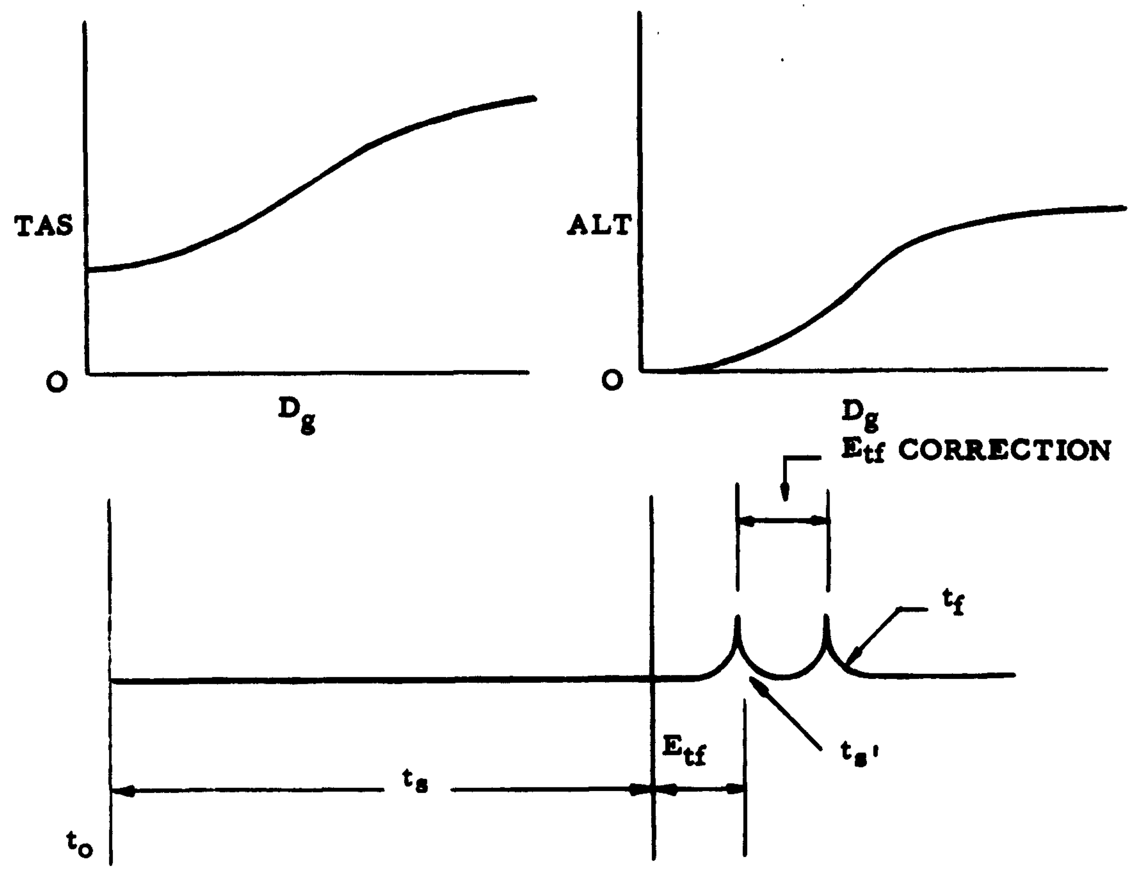


Figure 35. TAS and Altitude Profiles and Derivation of t_s

The third major quantity that must be known is the scheduled time of landing (STL). From STL it is possible to determine how much time the aircraft has left to fly according to schedule (t_s). Real clock time (RCT) subtracted from STL will give t_s.

A secondary parameter that is required to make an accurate computation is wind. The true ground speed (TGS) for an aircraft is equal to the true airspeed (TAS) plus the component of wind influencing the aircraft on the route.

The computer uses voltage analogs of velocity and route coordinates, time as an analog of D_g, and a numerical accumulation of a variable frequency as an analog of time. A complete analog flight is made and the results are used to extrapolate the aircraft's schedule. The simulation computer rate is 400 microseconds for each mile of distance. Since the D_g Generator operates at 25 kc, there is one cycle per 0. 1 mile. Although the aircraft is approaching touchdown, the computer actually simulates a reverse flight from the touchdown point to the aircraft's position. This somewhat simplifies the determination of schedule coordinates.

Figure 36 is a simplified block diagram of the flight simulator portion of the Analog Computer. The operation is as follows: The velocity (TAS) is generated as a function of distance and is used to control a voltage-controlled oscillator

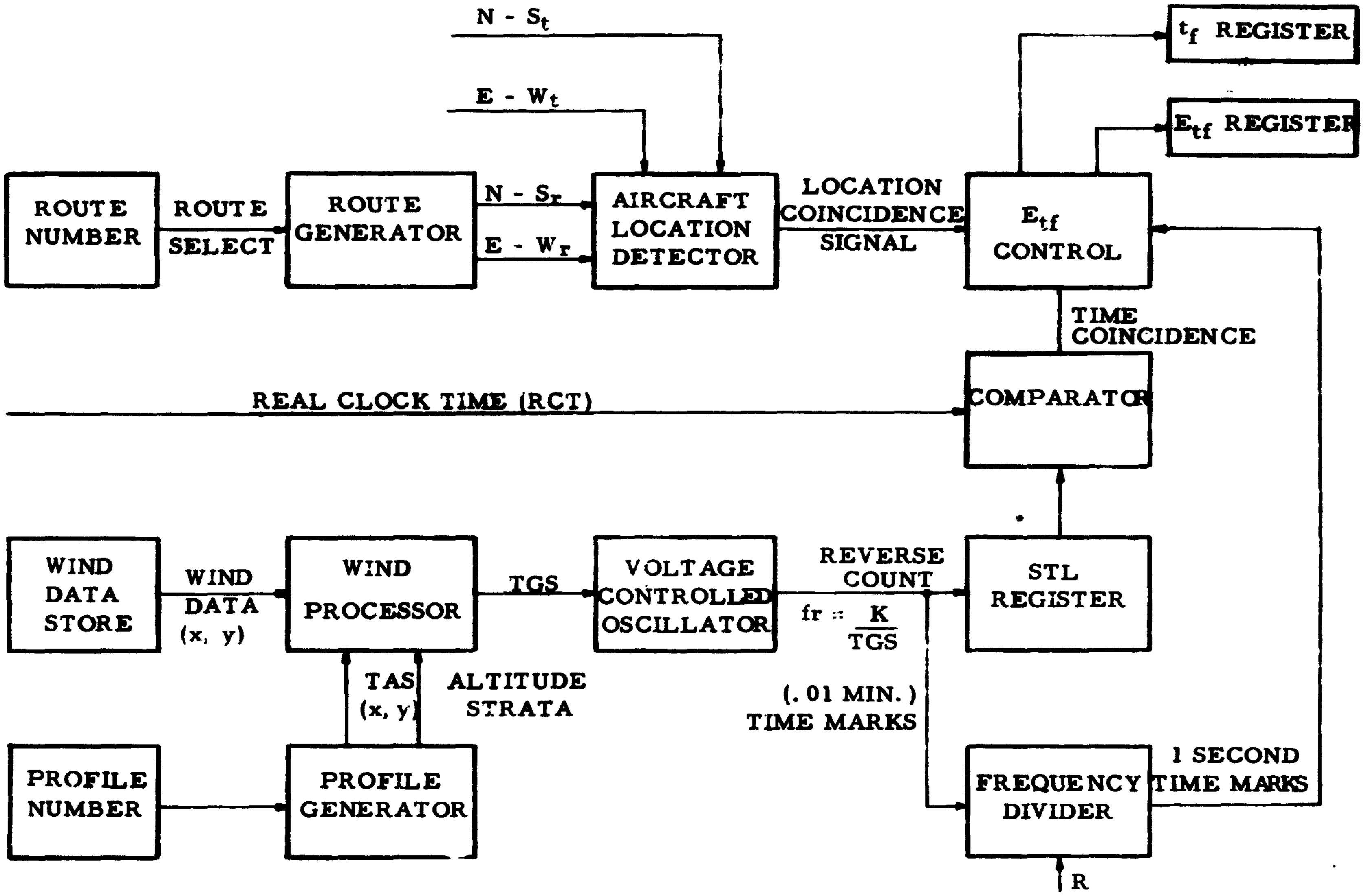


Figure 36. Analog Computer, Simplified Block Diagram (Mode A)

which feeds the time accumulators. D_g is fed to the profile generators and the route generator. The outputs of the route generator are then compared to the outputs of the radar Trackers. At the time (in analog time) that the computer coordinates are equal to the Tracker coordinates, the analog time it has taken the computer to fly out to that point is directly analogous to the time it will take the aircraft to fly to touchdown. At this stage, none of the control functions have been shown. Note that the above description is for Mode A operation.

The aircraft location detector must be a rather sophisticated device. This can be seen by considering what happens if the aircraft is slightly off the route that the computer thinks it should be on. Under these conditions, it is necessary to make some approximation as to where the aircraft is with respect to the route, for use in determining the actual time to fly. The assumption used in the Analog Computer is that the target aircraft has the same amount of time to fly as an aircraft would have if it were located at the foot of the perpendicular from the target aircraft to the route. This is illustrated in figure 44. For Mode B operation, it is not necessary to make use of the aircraft location detector since actual time to fly is not used.

The next thing to consider is the generation of true air speed. True air speed is provided (as a function of D_g) from the TAS profile by the true airspeed generator. A simplified block diagram of this is shown in figure 37.

Wind can now be taken into account by solving the following equation (see figure 38).

$$TGS = W \operatorname{Cos} (w - \Psi) + \sqrt{(TAS)^2 - W^2 \sin^2 (w - \Psi)}$$

This equation takes into account the crab angle that the aircraft must take up in order to maintain its position on the route. If crab angle is neglected, the equation becomes $TGS = TAS + W \cos (w - \Psi)$.

Wind is entered into the computer in the following manner: On the front panel of the computer there are two sets of thumbwheels for each of eight altitude levels. The wind magnitude and wind angle are set on these thumbwheels. If there is a wind change from one time to another and this change is set in immediately, it would cause a significant transient in the system. Therefore, there is a special slow-down program to prevent fast entry of wind into the computer.

For Mode B operation, a time from touchdown is generated which corresponds with the scheduled time the aircraft has to fly. As the simulated aircraft flies out, it reaches a point where its scheduled time to fly from touchdown is indicated by a signal. The coordinates of that point are memorized and digitized. This information is stored and later used for printing the Mode B circle coordinates.

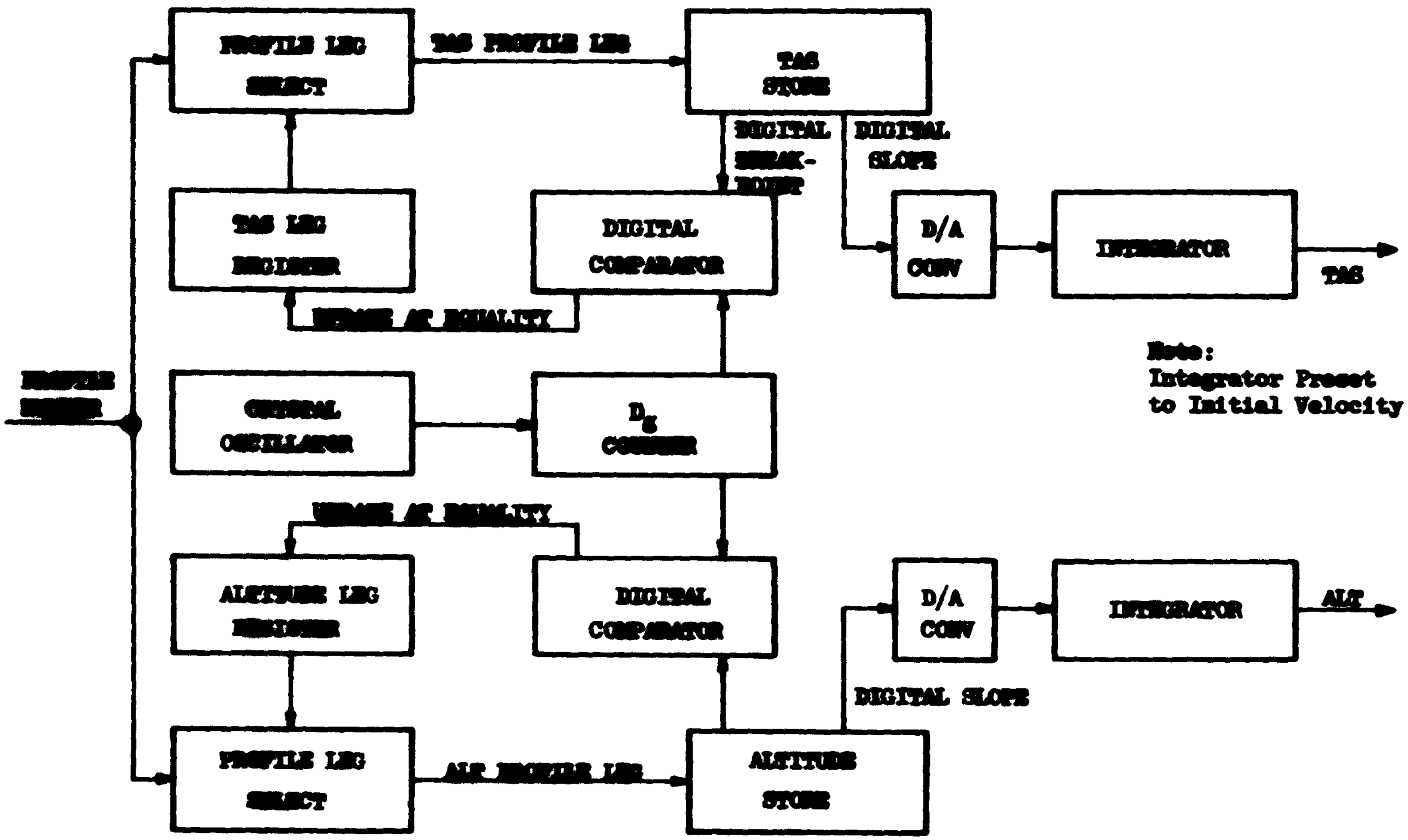
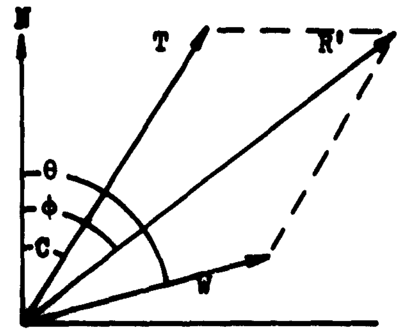


Figure 37. Profile Generator, Block Diagram



T = TAS
R = TGS
W = WIND MAG.
C = HEADING
ϕ = LEG
θ = WIND

$$T \sin C + W \sin \theta = R \sin \phi$$

$$T \cos C + W \cos \theta = R \cos \phi$$

$$(R \sin \phi - W \sin \theta)^2 = (T \sin C)^2$$

$$(R \cos \phi - W \cos \theta)^2 = (T \cos C)^2$$

$$R^2 \sin^2 \phi - 2(R \sin \phi)(W \sin \theta) + W^2 \sin^2 \theta = T^2 \sin^2 C$$

$$R^2 \cos^2 \phi - 2(R \cos \phi)(W \cos \theta) + W^2 \cos^2 \theta = T^2 \cos^2 C$$

$$R^2 - 2RW(\sin \phi \sin \theta + \cos \phi \cos \theta) + W^2 = T^2$$

$$R^2 - 2RW \cos(\theta - \phi) + W^2 - T^2 = 0$$

$$R = \frac{2W \cos(\theta-\phi) \pm \sqrt{\left[2W \cos(\theta-\phi)\right]^2 - 4(W^2 - T^2)}}{2}$$

$$= W \cos(\theta-\phi) \pm \sqrt{W^2 \cos^2(\theta-\phi) - W^2 + T^2}$$

$$= W \cos(\theta-\phi) \pm \sqrt{W^2\left[\cos^2(\theta-\phi) - 1\right] + T^2}$$

$$R = \text{T. G. S.} = W \cos(\theta-\phi) + \sqrt{T^2 - W^2 \sin^2(\theta-\phi)}$$

Figure 38. Wind Processor

In determining the error in time to fly for Mode A operation, a combined operation is used to determine the error. As in Mode B, a scheduled Time to Fly pulse is generated. The method of generating this pulse will be explained later. In the aircraft location detector, a signal is generated at the time corresponding to equality of the coordinates of the true and simulated aircraft. Thus, there are two pulses occurring in the fast time simulator, one corresponding to scheduled time to fly and the other to actual time to fly. These are analogs of the times the actual aircraft is concerned with. Therefore, the difference in time between these two signals is an analog representation of the error in time to fly. This can be converted to error in time to fly in digital form (the form it must have for display) by having a counter driven by a time analog clock accumulate counts between the two pulses. Appropriate frequency scaling will put ETF into the correct units. The pulse which occurs first tells the polarity of the error (ahead of or behind schedule). It should be remembered that the aircraft simulator is actually flying backwards with respect to the airplane.

The route, profile, and STL parameters are entered into the computer in digital form from the Video Track Programmer. These are sent to a special storage register. The route number goes through a Route Select Matrix which has one output for each of the routes available in the route file and the matrix selects the route for this computation. The profile number similarly selects the appropriate profile.

1. 7. 4. 2. 1. 2 DETERMINATION OF t_s

STL is used by the computer to determine the scheduled time to fly of the aircraft. Knowing the scheduled time of landing and the real clock time (available to the computer in digital form from a special digital clock), t_s can be determined analytically from the equation

$$t_s = RCT - STL$$

where RCT = real clock time. In the computation, the subtraction is done in a synchronous digital fashion.

Real clock time is held in digital form and STL is counted backwards at a rate corresponding to the analog time scale of the voltage-controlled oscillator (VCO). That is, STL is in hundredths of minutes and a hundredth of a minute is represented by one complete cycle from the VCO. Therefore, each pulse from the VCO will subtract 0.01 minute from STL. When STL is equal to real clock time (assuming count-back started the same instant as the fast flight simulation), the accumulated time of fast flight corresponds to scheduled time to fly.

1. 7. 4. 2. 1. 3 DIGITIZING

At scheduled time to fly in Mode B operation, the conversion of Mode B circle coordinates into digital form is done by holding the route coordinates and setting the computer into a digitize mode. During the digitize mode, the scheduled coordinates and altitude from the Tracker are digitized so that they may be sent to the Video Track Programmer for later print up. The analog-to-digital converter will be described later.

The generation of t_f in digital form, for use by the Video Track Programmer for electromechanical print up, is done by starting a counter at the beginning of the flight simulation and stopping the counter at analog actual time to fly.

In Mode B operation and in the missed approach time box display, the digital representation of the route coordinates are read into the Analog Computer and are converted from digital to analog form. The analog information is sent to the display units for positioning of the schedule circles or missed approach crosses.

For Mode B operation, it is necessary to store the East-West and North-South coordinates so that they may be digitized when scheduled time to fly occurs in the analog fast-time flight. This is done in the following manner: When scheduled time to fly occurs, the D_g generator is cut off. The fast time generator (VCO) is also stopped, since the simulated flight has ended. The x and y coordinates are held at the output of the route function generator by bringing the route coordinate integrator inputs to zero. The coordinates are now available for digitizing.

1. 7. 4. 2. 1. 4 SPECIAL OPERATIONS

There are several special operations carried on by the computer. If the aircraft is more than a predetermined time ahead of schedule, instead of sending an error in time to fly, a path-stretch recommendation is sent. This is a recommendation giving a heading change and a time during which the aircraft should follow the heading change in order to reduce its ETF below a preset level. If the aircraft is too far off schedule, then a lost aircraft indication is given which prints all Xs in place of ETF.

1. 7. 4. 2. 1. 5 MODE A COMPUTATION

The operation of the Terminal Area Computer in Mode A is as follows: The route, profile, and the fast-time generators are in a reset position (zero set) prior to and during the flight plan message from the Video Track Programmer. As soon as the flight plan message has been read in, a subtraction between the old smoothed ETF of the previous computation (ETF) and (STL minus RCT) is taken to get the old smoothed actual time to landing, in order to determine the new correction in error in time to fly to be used in this computation. The reason for this is

described later.

When the subtraction is completed, the routes and profiles included in the flight plan message are switched in and a settling time is allowed for the route and profile generators. At this point, the fast-time generator and D_g generators are started, thereby allowing the simulated flight to begin. Simultaneously, a counter is gated on to begin the count of the actual time to landing (t_f which is printed on the electromechanical Approach Display). The flight simulation is now in progress. The aircraft location detector is continuously checking for coincidence and the wind computer provides TGS by adding appropriate wind correction to TAS. Two things occur during the simulation. Coordinate coincidence for t_s and t_f is encountered at two individual points in the fast flight. The first pulse starts a counter operation to measure the change in error in time to fly. This error count continues until the other of the two pulses occurs. After both pulses have been generated, a check is made of error in time to fly to see if a path-stretch command is required of if a lost-aircraft signal is required. There is an override timer so that if the entire computation takes too much time, a lost aircraft signal is given and all data except altitude is ignored. A lost aircraft is indicated by printing of Xs in place of error in time to fly. After the simulation, Tracker altitude (if available) is digitized. The path-stretch information is determined by taking the value of error in time to fly and interrogating a path-stretch logic network to determine the path-stretch to be recommended.

1. 7. 4. 2. 1. 6 MODE B OPERATION

Mode B operation is very similar to Mode A operation so far as the analog fast flight is concerned. However, there is no requirement for the subtraction of old ETF from STL, since ETF is not used. Therefore, after the flight plan has been read in and settling time is allowed, computation by simulation takes place and continues until scheduled time to fly has been reached. At this point, the fast time generator and the D_g generator are stopped and the route coordinates are held throughout the digitize portion. The digitize portion in this case, includes digitizing of the scheduled East-West and North-South coordinates produced by the route generator.

1. 7. 4. 2. 1. 7 RAPID PRINT UP

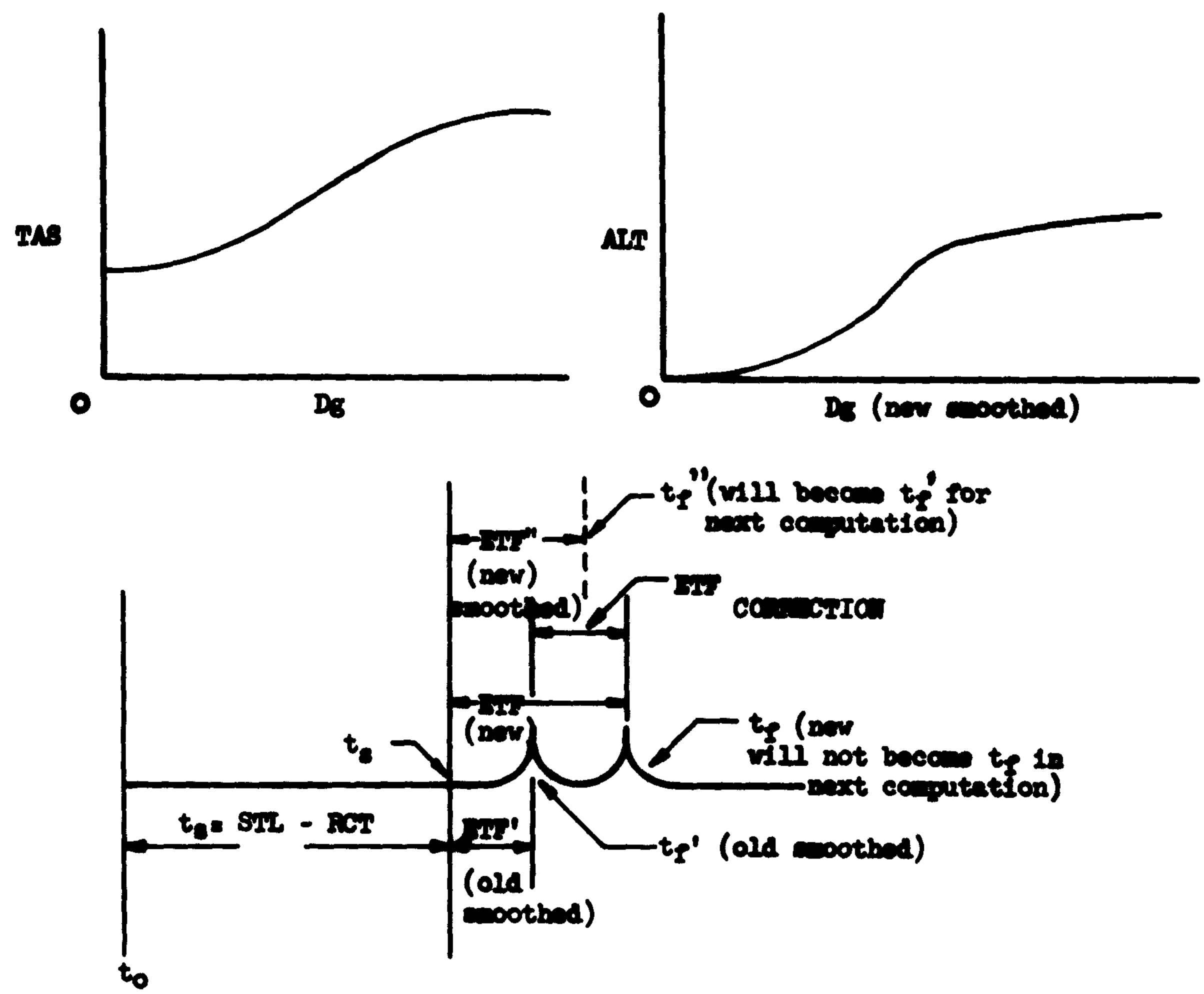
It is required that print up of the display information be completed in 100 milliseconds and not repeated for from 3 to 20 seconds. This requires that the North-South and East-West coordinates in Mode B operation be converted to digital form and stored on the drum of the Video Track Programmer. During rapid print up, these coordinates are read back into the Analog Computer and are converted from digital to analog form by portions of the circuits used for prior analog to digital conversion. This analog voltage is sent to the Video Conditioner for positioning of the schedule circles. In addition to this, the Character Generator requires

information to produce an offset leader. That is, the differences between the Tracker coordinates and the Mode B circle coordinates are required. These are generated by using the operational amplifiers to take the difference between the fast flight route coordinates and the Tracker coordinates.

1.7.4.2.1.8 ERROR SMOOTHING

In the Analog Computer, noise or error could cause an erroneous computation and a radical change in ETF could appear. In order to minimize these radical changes in error in time to fly, a smoothing technique is used. It is valid to make use of the smoothing technique, since the error in time to fly cannot change radically in a physical situation. Therefore, the change in error in time to fly can legitimately be limited in the computer. This limiting is done as follows:

In the computer, without error smoothing, a signal was generated during the simulated flight at scheduled time to fly, as determined by the difference between scheduled time of landing (STL) and real clock time (RCT). This t_s pulse was used to start or to stop a counter, depending on the polarity of error. The t_f pulse (a pulse occurring in analog time at coordinate coincidence) was used to stop the count or start the count as the case may be. The time interval between the t_s pulse and the t_f pulse was a time interval corresponding to error in time to fly and the scaling of the counter was such that error in time to fly would be generated in seconds. This method accomplishes the smoothing by generating in place of t_s, a pulse which is called t_f'(see figure 39). This pulse is t_s plus or minus the old smoothed ETF from the previous computation. This is done in the following manner: The ETF from the previous computation is read into the computer with the flight plan. This old ETF' is then added or subtracted, depending on the polarity of the ETF to or from STL. After this addition or subtraction has been made, the computation for t_s now generates a pulse, t_f' by comparison of real clock time and the STL plus or minus the old error in time to fly. The nature of t_f' is such that if there were no change in error in time to fly between the two computations, the t_f' would occur at t_f in the new computation. However, if there is a change in the error in time to fly, then the interval between t_f' and t_f (coincidence) is proportional to the change in ETF. To obtain a new smoothed ETF, a small fraction (for example 1/4) of the change in ETF is added to or subtracted from ETF. In other words, rather than adding the total ETF correction, the correction can be added at a rate of 1/4 actual value so that only 1/4 of the correction is entered during each computation. Actually any rate can be used, allowing for various rates of smoothing. It is interesting to note that the change in ETF is an acceleration function.



ETF = New error in Time To Fly

ETF' = Old error in Time To Fly

ETF'' = New smoothed error in Time To Fly

ETF'' = ETF' + K(ETF-ETF')

Figure 39. Derivation of New Smoothed Error in Time To Fly

Figure 39. Derivation of New Smoothed Error in Time to Fly

1.7.4.2.2 **DETAILED PRINCIPLES OF OPERATION**

1.7.4.2.2.1 **AIRCRAFT SIMULATOR**

1.7.4.2.2.1.1 **RESOLVER AND ROUTE INTEGRATOR** - Figure 40 is a block diagram of the resolver and route integrator portions of the aircraft simulator. The symbol Ψ indicates the leg angle voltage and is generated as a function of distance from touchdown by the route and profile store assembly. The route and profile store assembly provides Ψ in digital form and one of the digital to analog converters is used to convert Ψ to analog form.

The resolver drive, sine summation, and cosine summation make up a twelve segment sine-cosine function generator. The resolver drive is made up of the input operational amplifiers and the input function generator network. In this case, there are two input networks in order to provide an effective dynamic range of approximately 140 volts. The sine summation sums the sine weighted summing legs and the cosine summation sums the cosine weighted legs. The output information is thus the sine of the leg angle volts Ψ and the cosine of leg angle volts Ψ . Real time is proportional to distance, thus, the integral of sine Ψ with respect to time is equivalent to the integral of sine Ψ with respect to distance, which is the East-West route coordinate as a function of path distance. Similarly, the integral of the cosine gives the North-South coordinate. The integrators are made up of operational amplifiers with .1-microfarad feedback capacitors. The reset switching of these integrators is a feedback type switching operation that minimizes drifts. The switches used for this operation are high-current transistor switches because of the high currents involved in discharging the integrating capacitor.

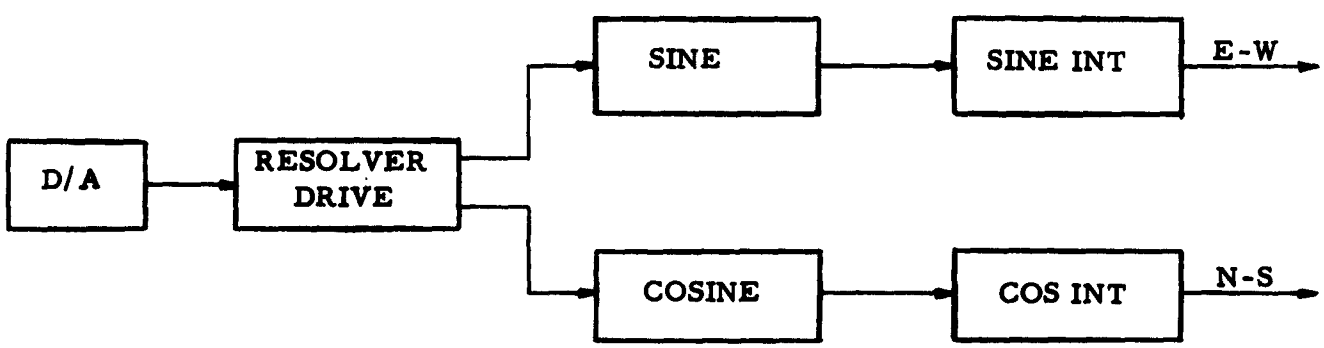


Figure 40. Resolver Enroute Integrator

1.7.4.2.2.1.2 <u>PROFILE INTEGRATORS</u> - The route and profile store assembly provides the slope of the TAS versus distance to go to touchdown (D_g) and altitude versus D_g curves. Essentially these are $\frac{d(TAS)}{dD_g}$ and $\frac{d(Alt)}{dD_g}$.

These come from the route and profile store assembly in digital form and are converted to analog form by digital-to-analog converters. The analog information is then integrated by the profile integrators which are similar to the route integrators. The true airspeed is then routed to the wind processor assembly for combination with wind data to provide true ground-speed. The altitude information goes into an altitude intervalizer which is a function generator network modified to become a multi-level comparator. The output of this intervalizer is a set of signal lines, one for each of the altitude regions. The [illegible] indicates the altitude region of the input. This information is used in the wind processor to select the appropriate wind level information. Figures 41 and 42 are profile integrator block diagrams.

Figure 41. Wind Profile Integrator

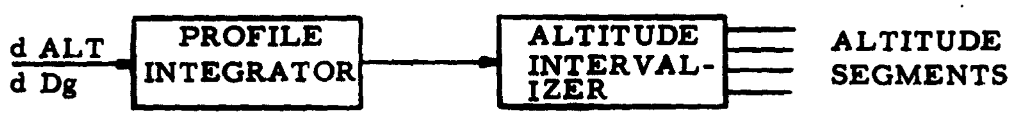


Figure 42. Altitude Profile Integrator

1.7.4.2.2.1.3 <u>VOLTAGE-CONTROLLED OSCILLATOR</u> - Figure 43 is a functional block diagram of the voltage-controlled oscillator. The comparator compares the integrator output with the input voltage. The integrator can be switched to integrate in a positive direction or a negative direction. When the output of the integrator is equal to the input voltage, the flip-flop is switched so that the integrator changes direction and integrates toward ground. When the output of the integrator is at ground potential, the flip-flop switches again and the integrator integrates upwards to the input voltage. This system provides an output frequency which is proportional to the inverse of the input voltage, as is required for the voltage controlled oscillator. Preliminary breadboard data showed that linearities and accuracies of 0.1 percent could be achieved with this method.

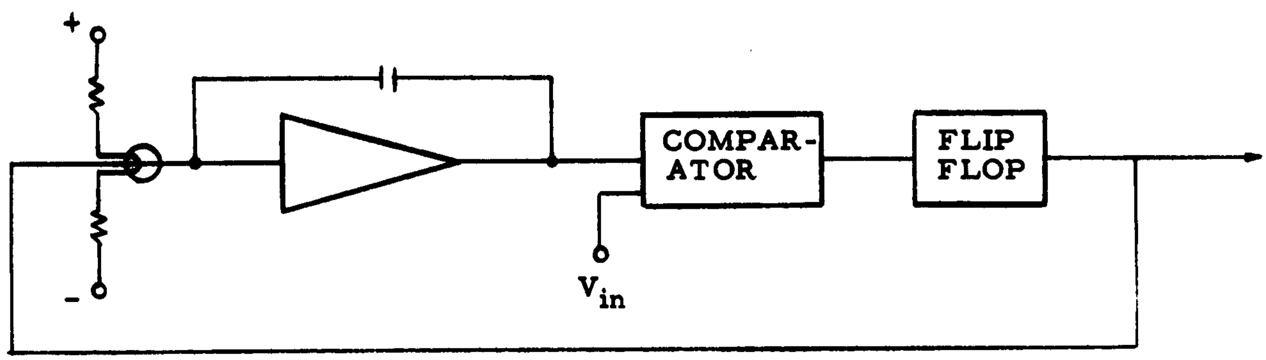


Figure 43. Voltage Controlled Oscillator

1.7.4.2.2.2 AIRCRAFT LOCATION DETECTOR

The purpose of the aircraft location detector is to compare the coordinates of the actual position of the aircraft with the instantaneous coordinates of the simulated aircraft while on its simulated backward flight from the touchdown point.

The aircraft location detector indicates the coincidence of the simulated aircraft with the position of the actual aircraft by generating a coincidence pulse (T_f). This pulse is used (in Mode A operation only) as a start or stop control for the E_{tf} accumulators.

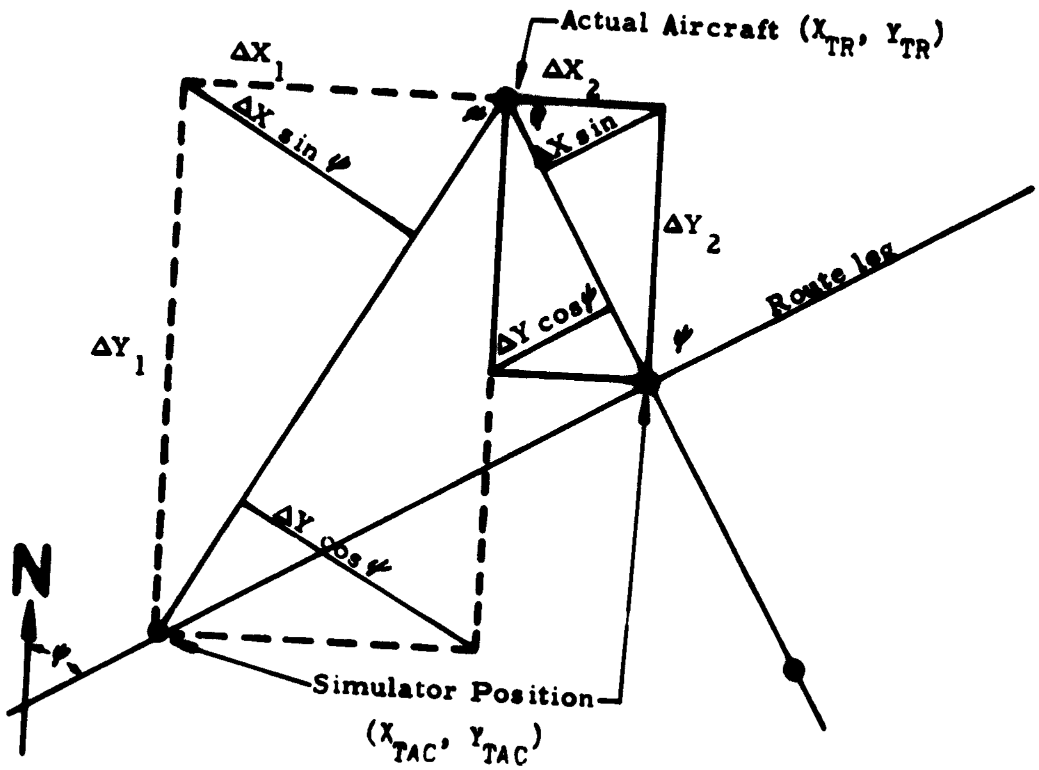
The operation described above would be relatively simple if the actual aircraft were always on course. However, the actual aircraft may be as much as five miles off-course. Thus, a need exists for an off-course detector.

1.7.4.2.2.2.1 OFF-COURSE DETECTOR - For an aircraft that is off-course (5 miles max. on either side of the airway center), the computer generates a -12 volt pulse (t_f) at the point on the route which is the projection of the aircraft's position normal to the leg of the route.

This projected route position is determined by comparing tracker coordinates (volts) of the aircraft with the route coordinates (volts) developed by the Analog Computer. Any off-course coordinates result in a difference:

$$(X_{TAC} - X_{TR}) = \Delta X \text{ and } (Y_{TAC} - Y_{TR}) = \Delta Y.$$

The ΔX and ΔY (volts) as well as leg angle volts (ψ volts) are set to the off-course computer for solving the following trigonometric equation: $\log \tan \psi - \log \Delta Y + \log \Delta X = 0$. This equation may be derived directly from the geometry of figures 44 and 45. During coincidence, $\Delta X \sin \psi$ must equal $\Delta Y \cos \psi$.



$\Delta X = X_{TR} - X_{TAC}$

$\Delta Y = Y_{TR} - Y_{TAC}$

ψ = Route leg azimuth

Figure 44. Off-Course Aircraft Solution

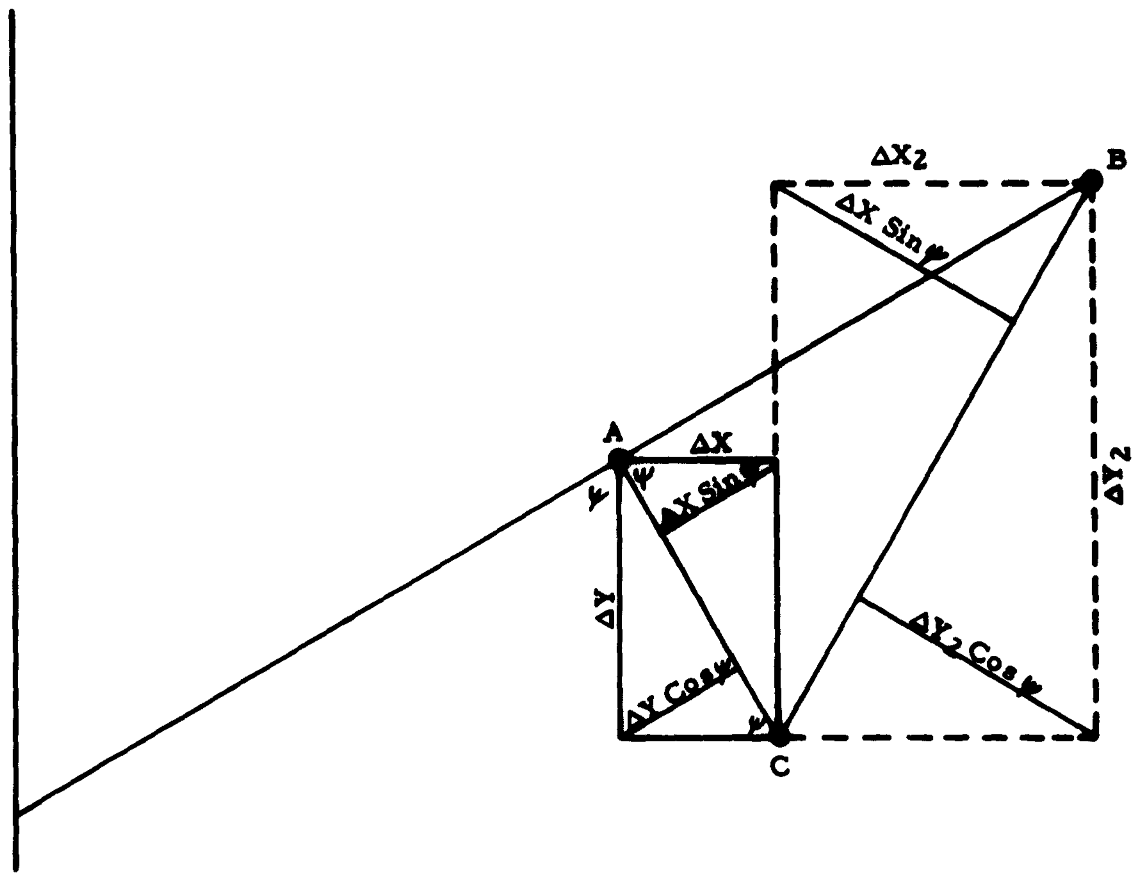


Figure 45. Ambiguous Solutions

Therefore, $\Delta X \sin\Psi = \Delta Y \cos$

and $\dfrac{\sin\Psi}{\cos\Psi} = \dfrac{\Delta Y}{\Delta X}$

so $\log \dfrac{\sin\Psi}{\cos\Psi} = \dfrac{\Delta Y}{\Delta X}$

and $\log \sin\Psi - \log \cos\Psi = \log \Delta Y - \log \Delta X$

and $\log \tan\Psi = \log \Delta Y - \log \Delta X$

therefore $\log \tan\Psi - \log \Delta Y + \log \Delta X = 0$

The comparator senses the conditions for equality of the equation and a -12 volt pulse is generated as the Analog Computer sweeps through the projected aircraft position normal to the route leg.

It is obvious that there are conditions that produce false solutions (figures 44 and 45, dotted lines). To inhibit these false solutions, logic signals are developed from the ΔX and ΔY polarity with respect to position and with respect to quadrant.

To keep the hardware practical, the following design choice was made: Log ΔX and log ΔY function generators are 2-1/3 decades with range ± 0.025 mi. $\leq \Delta X \leq \pm 5.0$ mi. and ± 0.025 mi. $\leq \Delta Y \leq \pm 5.0$ mi.

The lower limit is considered well within required tolerances. The upper limit is chosen from the stipulated airway width of ±5 miles either side of the airway centerline. A polarity resolver precedes each log generator driver operational amplifier in order to convert to the absolute value of the coordinate.

The log trig function range is $1° \leq \Psi \leq 89°$ because $\log \sin \Psi \rightarrow -\infty$ as $\Psi \rightarrow 0°$ and $\log \cos \Psi \rightarrow +\infty$ as $\Psi \rightarrow 90°$ (see figure 46).

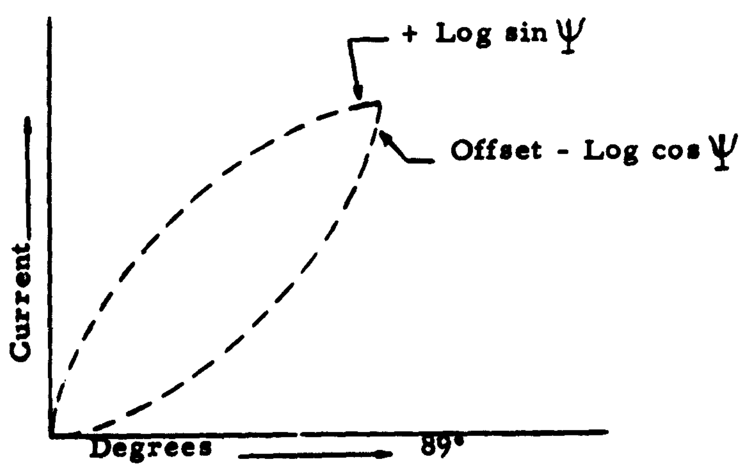


Figure 46. Generation of Negative Log Cosine Ψ

A quadrant resolver precedes the log trig function generator in order to sense the quadrant of the region and to sense when the angle is within the ranges of 0° ± 1°, 90° ± 1°, and 270° ± 1°.

From the polarity resolver and quadrant resolver, logic circuits are actuated to handle the excluded regions of the function generators as special solutions.

The inputs to the location detector which are used to generate the equation are leg angle volts Ψ (zero to 18 volts for 0° to 90°), Tracker coordinates minus Analog Computer coordinates $\pm \Delta X$ and $\pm \Delta Y$. Quadrant logic is supplied to the location detector from the Analog Computer.

The aircraft location detector chassis contains eleven cards. Three of these cards are used for altitude and the other eight cards function as the aircraft location detector.

The $\pm \Delta X$ and $\pm \Delta Y$ inputs go directly to the polarity generator card. This card produces the absolute value of ΔX and ΔY and develops the inhibit logic. The operational amplifier card contains four amplifiers. Amplifier No. 2 and No. 3 drive the polarity generator card. Amplifiers No. 1 and No. 4 drive the Log ΔX function generator card and Log ΔY function generator card respectively.

The two diode function generator cards are basically similar. One diode function generator produces a current proportional to positive log ΔX and the other produces a current proportional to the negative log ΔY. The positive Log ΔX is then summed with the negative Log ΔY to produce Log ΔX - Log ΔY. This signal is summed with the Log tan Ψ before being sensed by the comparator.

Log Tan Ψ is produced by the difference of log sin Ψ and log cos Ψ.

At the input to the comparator, the signal (log tan Ψ) is also summed with $\log \frac{\Delta Y}{\Delta X}$.

When $\log \tan \Psi = \log \frac{\Delta Y}{\Delta X}$, the current is zero. The comparator senses this null and generates a 12-volt step. This step voltage drives the coincidence pulse generator card which produces a minus 12-volt pulse.

The coincidence solution described above will fail or give erroneous answers for a route leg on an azimuth of 0°, 90°, 180°, or 270°. To eliminate this problem, the special solution acceptance cards No. 1 and No. 2 generate a coincidence pulse output if the ΔX (or ΔY as the case may be) along a route leg of 0°, 90°, 180°, or 270° is less than 0.025 mile. If the aircraft is directly on the route, these cards will produce an output pulse if both ΔX and ΔY are less than 0.025 mile.

The special solution card No. 1 contains four sensors to detect when ΔX and ΔY are less than 0.025 mile or greater than 5 miles. These sensors feed the AND and OR circuits on special solution card No. 2. Two sensors on card No. 2

determine when one of the four critical route angles listed above is being used.

In some cases, it is conceivable that both the special solution circuits and the regular solution circuits could give an output at the same time. This is entirely satisfactory and acts as an added safety factor.

1. 7. 4. 2. 2. 3 <u>WIND PROCESSOR</u>

1. 7. 4. 2. 2. 3. 1 <u>WIND COMPUTATION</u> - Figure 38 shows the derivation of the equation to be solved to provide true ground speed (TGS) from true airspeed, leg angle, wind angle and wind magnitudes. Figure 48 is a block diagram of the wind processor assembly. The altitude information is segmentized into discrete outputs that consist of eight signal lines. One line is activated at a time, indicating the range of altitude that is correct at that instant of simulator time. This altitude information drives the angle and magnitude switching assemblies to switch in the proper wind angle and wind magnitude as a function of altitude. The magnitude and angle information is indicated on potentiometers driven by d-c motors. The angle information is taken off the potentiometer in the form of a voltage and the difference taken between the leg angle voltage and the wind angle voltage. This angle difference is then resolved into the appropriate quadrant for application to a one-quadrant sine-cosine function generator. The sine and cosine of the angle difference are then each applied to the top of separate wind-magnitude potentiometers. Thus, the wiper arm of the potentiometer gives wind magnitude times the sine and cosine of the angle difference respectively. It can be noted from the equation that these are two of the terms required for solution of the true groundspeed equation. The resolver used to break the angle information into 90-degree segments can not provide quadrant information to select the proper polarity of the W cosine term. The square root of the sum of the squares of true airspeed and the sine term are taken by a stepped angle summer. This technique is derived from a paper by Marion Winkler presented at the 1958 IRE Wescon entitled "Network Solution of the Right Triangle Problem". This square root of the difference of the squares information is resistively summed with the cosine term and the output information is now a true groundspeed. The true groundspeed information is then converted to a frequency which is proportional to the inverse of the true groundspeed as described earlier.

1. 7. 4. 2. 2. 3. 2 <u>WIND ENTRY TECHNIQUE</u> - Figure 47 is a brief functional block diagram of the wind updating (or entry) technique. The Weather Bureau wind magnitude and direction data are inserted by setting a series of ten-position switches on the front panel. When an interrogate line is activated, then the settings of the switches are essentially read out in decimal form. This information is then nverted from decimal to binary-coded decimal. The binary-coded decimal infor- ation goes to a digital-to-analog converter where the wind switch setting is finally read out in analog form.

This analog voltage information from the switches is compared to the voltage across the corresponding potentiometer setting of the potentiometer store which is normally used for computation. The potentiometer store is compared to the digital-to-analog converter voltage and any discrepancy results in an output from the comparator. The polarity of the output will determine the direction in which the drive motor of the potentiometer store is pulsed. Thus, the system will incrementally approach the wind switch setting.

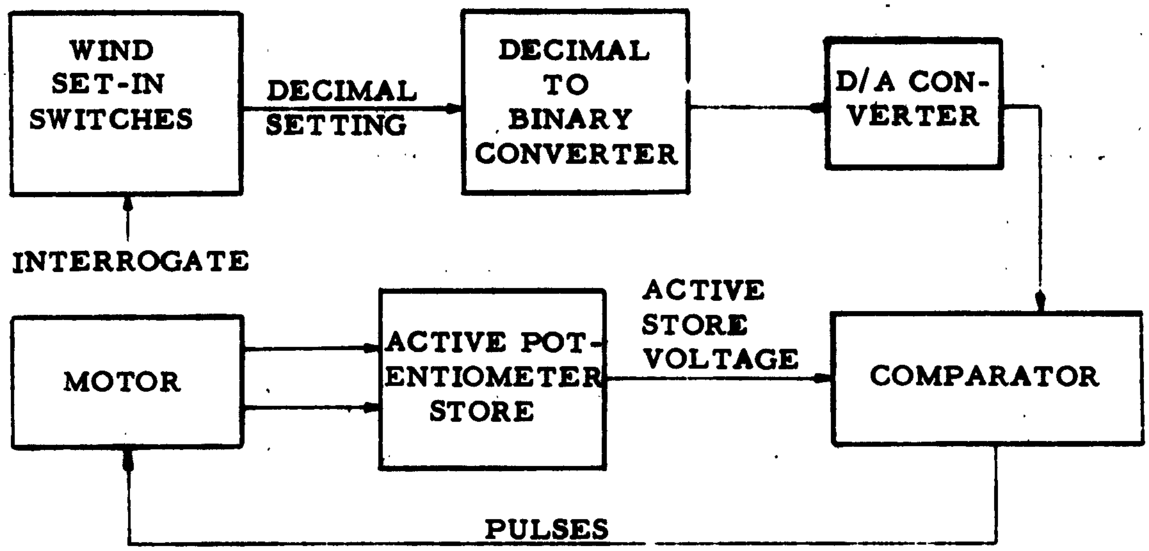


Figure 47. Wind Entry Technique

1.7.4.2.2.4 ROUTE AND PROFILE STORE

Figure 49 is a simplified diagram of the route and profile store coding. The route number is stored in the digital portion of the computer and the leg number is kept track of during the simulation. For each route leg number, one line is activated to the route and profile store assembly. This line goes to the store assembly where the lines are tied into data rows. There is one data row for each possible different route leg number. The next section of figure 49 shows the detail of the data row. The route leg select is coupled through a diode into an appropriate column. The connection from the diode to the column is by means of a taper pin. Figure 49 shows a sectional pictorial of this layout. When the route leg goes negative, then the specific column attached through taper pins is also pulled negative so that the output is the decimal form of the number that has been set up by means of the taper pins. In the case illustrated, the data row is coded for 67.3. This could be the slope in the case of profiles or the leg angle or the leg length. The decimal output is converted to binary-coded decimal and this then

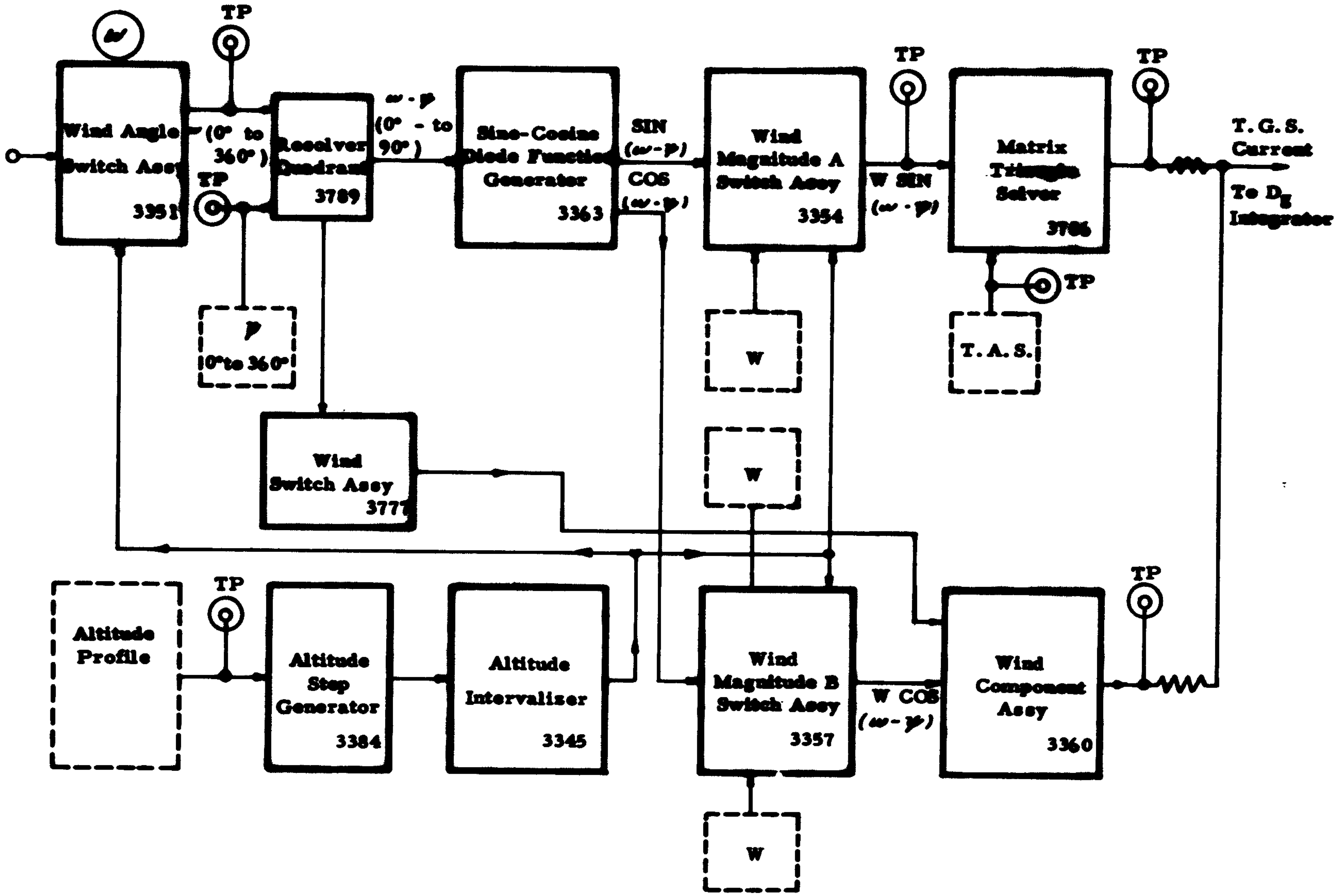


Figure 48. Wind Processor, Block Diagram

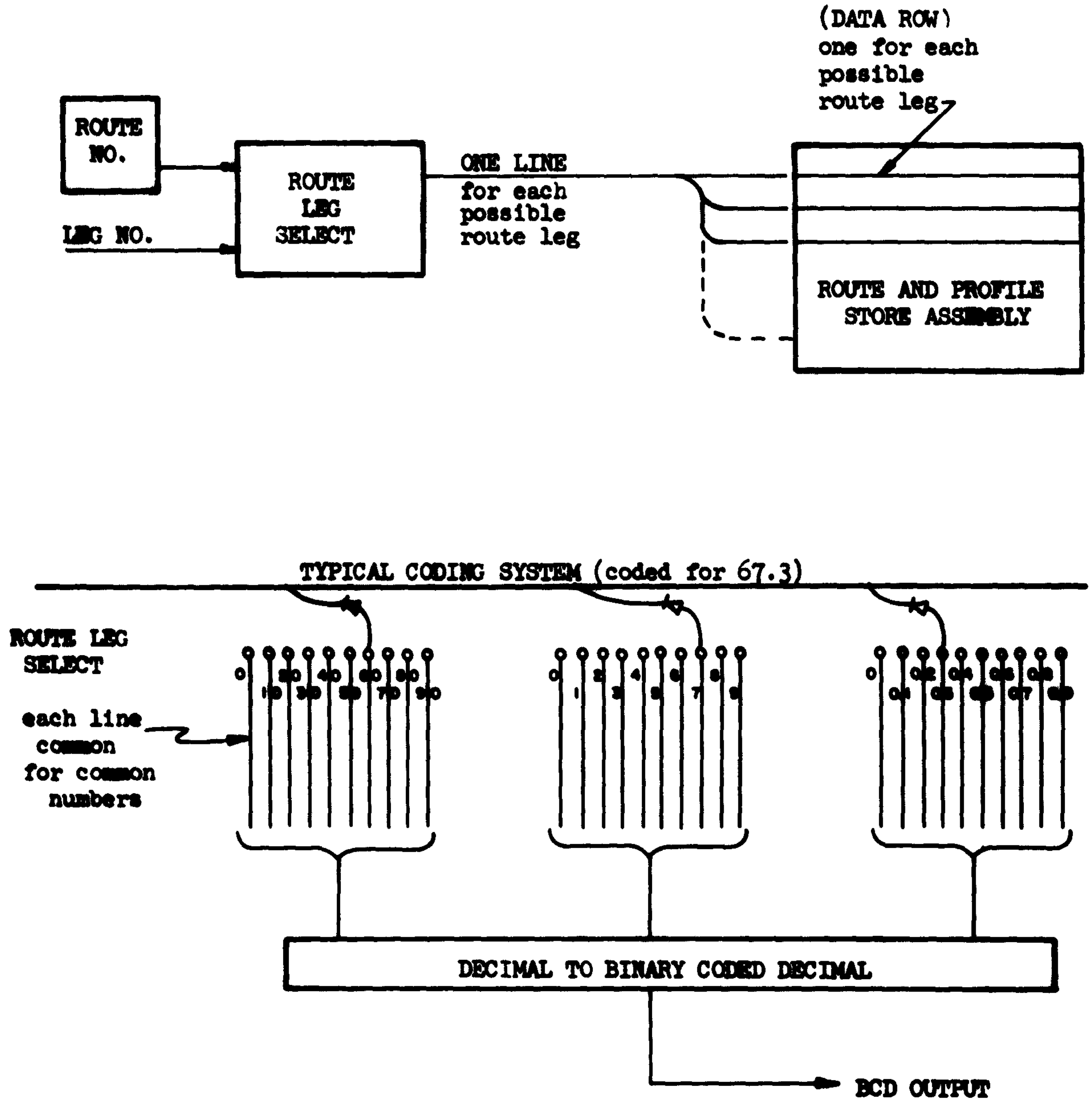


Figure 49. Route and Profile Store Coding

becomes the binary coded decimal output used in the Route and Profile Generator.

1. 7. 4. 2. 2. 5 DIGITAL SECTION

The digital portion of the Analog Computer is made up of a 53-bit flip-flop register, 2 state flip-flops, special purpose flip-flops, timing circuits and associated diode and transistor logic circuits.

The Video Track Programmer sends data to the register in binary-coded decimal and alpha-numeric form (see figure 50). The data is used for calculation of various analog and digital parameters. The results are then sent to the Video Track Programmer for updating the flight plan on the drum.

The flip-flop designations in this description have been arbitrarily chosen as follows: Flip-flops AA_{1-4}, AB_{1-8}, AE_{1-5}, AF_{1-5}, AG_{1-5}, AA_{1-8}, AJ_{1-7}, and AK_{1-4} form the register referred to above. Other symbols and abbreviations are explained in Table 4.

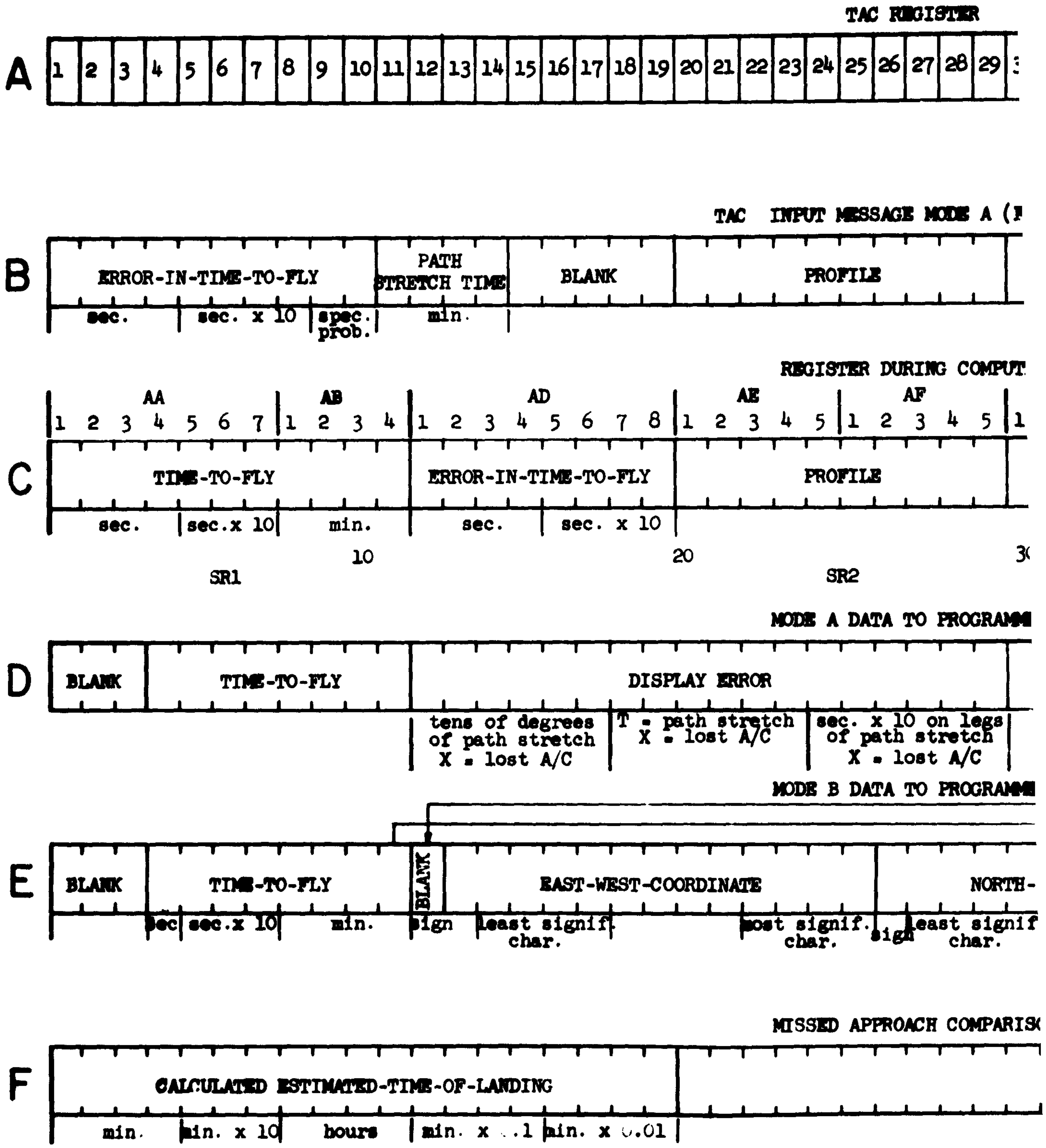
The Analog Computer is designed to operate in two main modes, Mode A and Mode B. However, two other modes are extensions of Mode A and Mode B. The Missed Approach and Special Problem Functions will operate in either Mode A or Mode B.

The operation of the system is semi-synchronous. That is, some operations are clocked (by any one of five clocks), and others are not clocked. State flip-flops and timing gates are used to control the sequence of events. Clock widths at the logic level are nominally 1 ± 0. 2 microseconds. The lower limit ensures that even the slowest flip-flop will reach the regeneration point during clock time. The upper limit prevents the possibility of a fast flip-flop switching and still leaves sufficient time for the next successive logical operation to occur in the same clock time.

Normal logical levels are 1 for values equal to or more negative than -8 volts (nominally -12 volts), and 0 for values equal to or more positive than -3 volts (nominally 0 volts).

1. 7. 4. 2. 2. 5. 1 INPUTS AND OUTPUTS - Digital data received from the Video Track Programmer (VTP) include flight plan data for computation, timing information and status data. The VTP sends a 144-kc clock (c) over a 75-ohm coaxial cable to the Analog Computer. The logic levels for the clock are 1 for values more negative than -2. 5 volts (nominally 0 volts). The coaxial cable carrying the VTP clock pulse is terminated at the Analog Computer and the clock pulses are then amplified to normal logic levels (-8 to -12 volts true, and 0 to -3 volts false). All other data from VTP comes over regular lines at normal logic levels. All data sent to VTP is at normal logic levels and of minimum one-bit duration.

1


TAC REGISTER
A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
TAC INPUT MESSAGE MODE A (
B
ERROR-IN-TIME-TO-FLY
PATH STRETCH TIME
BLANK
PROFILE
sec.
sec. x 10
spec. prob.
min.
REGISTER DURING COMPUT
AA
AB
AD
AE
AF
1 2 3 4 5 6 7
1 2 3 4
1 2 3 4 5 6 7 8
1 2 3 4 5
1 2 3 4 5
C
TIME-TO-FLY
ERROR-IN-TIME-TO-FLY
PROFILE
sec.
sec.x 10
min.
sec.
sec. x 10
10
20
SR1
SR2
MODE A DATA TO PROGRAM
D
BLANK
TIME-TO-FLY
DISPLAY ERROR
tens of degrees of path stretch X = lost A/C
T = path stretch X = lost A/C
sec. x 10 on legs of path stretch X = lost A/C
MODE B DATA TO PROGRAM
E
BLANK
TIME-TO-FLY
BLANK
EAST-WEST-COORDINATE
NORTH-
sec
sec.x 10
min.
sign
least signif. char.
most signif. char.
sign
least signif char.
MISSED APPROACH COMPARIS
F
CALCULATED ESTIMATED-TIME-OF-LANDING
min.
min. x 10
hours
min. x .1
min. x 0.01

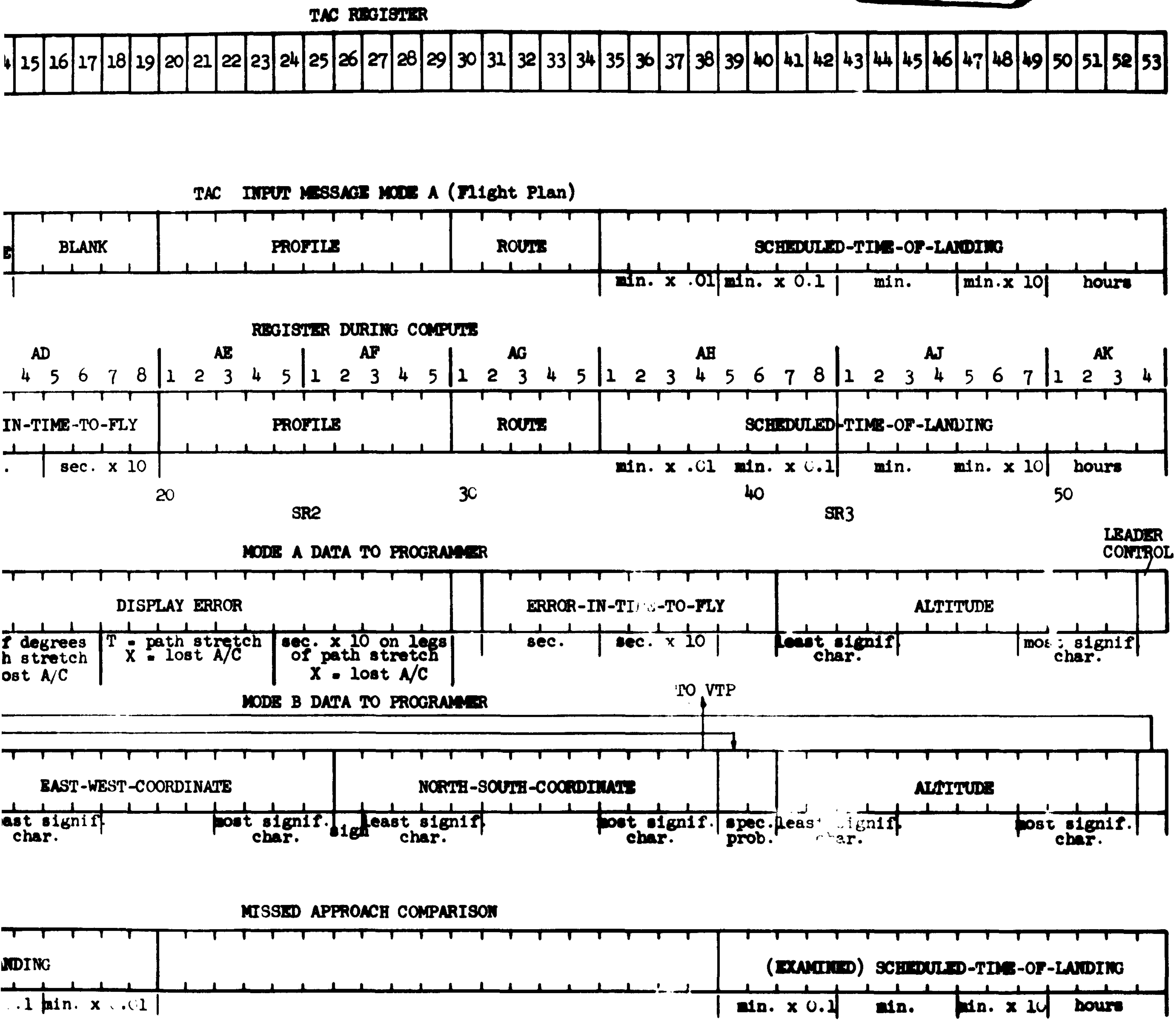


Figure 50. Shift Register Operations

TABLE 4. SYMBOLS AND ABBREVIATIONS

Symbol	Description
C	VTP Clock (144 KC)
C_1	100 KC fixed Clock
C_2	.01 min. Var. Clock
C_3	1 sec. Var. Clock
S. C.	Start Compute from VTP
C_4	ETF Count Clock
J1	Alt. Comparator
J2	E-W Comparator
J3	N-S Comparator
TA	Tracker Assign
M. B. P.	Mode B Print
M. A.	Missed Approach Gate
Sub Gate	Sub Gate
S. S. G.	Start Simulate Gate
T. S. G.	TAC Start Gate
A. C.	Aircraft Coincidence
AK_{1-4}	STL Hours
DG_{1-4}	10's Miles (D. G. Counter)
DG_{5-8}	1's Mile (D. G. Counter)
DH_{1-4}	.1 Mile (D. G. Counter)
KS_{5-7}	State Register
KS_{1-4}	Digitize Control
SP_{1-2}	Spec. Prob. Control
BB_{1-2}	10's of Mile or Quad
BA_{1-4}	1 Mile or 10 Degrees
BA_{5-8}	.1 Mile or 1 Degree
BA_9	.05 Mile
BL_{1-3}	Route Leg Resister
DA_{1-4}	Alt. Leg Resistor
DT_{1-4}	TAS Leg Register
DT_{5-8}	Time from Turn

TABLE 4 SYMBOLS AND ABBREVIATIONS (continued)

CONTROL FLIP-FLOPS

KT1	50 ms Lost Aircraft Timer
KT2	
KT3	Path Stretch Initiated
KT4	ETF Polarity, "Data No Good"
KT5	Path Stretch T = R. T.
KT6	Mode B
KT7	General Control F-F
KT8	Aircraft Coinc.

REGISTER COUNTING MODES

Register	Count Modules	Count Mode	Clock
1. AA_{1-4}	BCD	fwd.	C_3, C_2, C
2. AA_{5-7}	"5"	fwd.	
3. AB_{1-4}	BCD	fwd.	
4. AD_{1-4}	BCD	f-b	C_3, C_4, C_2
5. AD_{5-8}	BCD	f-b	
6. AH_{1-4}	BCD	f-b	C_2
7. AH_{5-8}	BCD	f-b	
8. AJ_{1-4}	BCD	f-b	
9. AJ_{5-7}	"5"	f-b	
10. AK_{1-4}	BCD	f-b	

Timing gates and data for digitizing come from the Analog Computer. The data for digitizing is produced by an analog-to-digital converter. Timing and gating signals are sent to the Analog Computer at various times during the computation. In addition, when required, digital information is set, through weighting resistors, onto operational amplifiers which convert the data to analog voltages.

The only other input to the register is the digital equivalent of real time which comes from the Time Clock Logic Assembly in the Analog Computer.

1.7.4.2.2.5.2 <u>MAIN REGISTER</u>

1.7.4.2.2.5.2.1 <u>SHIFT-IN OPERATION</u> - At the beginning of any of the four modes of operation, the data described above is shifted serially into the register. For serial shift-in, each flip-flop has an AND input. The clock pulse goes to each flip-flop. Any flip-flop will go true if the previous flip-flop is true AND the clock pulse is true. Any flip-flop will go false if the previous flip-flop is false AND the clock pulse is true. Some of the four modes of operation will not use all the information shifted in, but the order of the information shifted in (see figure 50) will always be:

1. Scheduled Time of Landing (STL):

   hours . . . . 4 bits

   tens of minutes 3

   minutes 4

   tenths of minutes 4

   hundredths of minutes 4

   19 bits total

2. Route: . . . . 5 bits

3. Profile:

   altitude . . . . 5 bits

   speed 5

   10 bits total

4. Blank: . . . . 5 bits

5. Path Stretch: . . . . 4 bits

6. Problem Digit: . . . . 1 bit

7. Sign of ETF: . . . . 1 bit

8. Error in ETF:

   tens of seconds . . . . 4 bits

   seconds 4

   8 bits total

The complete total is . . . . .53 bits

The above describes the input message from the Video Track Programmer to the Analog Computer register at the beginning of any mode of operation. Note that STL, Route, Profile, etc. are shifted into the register serially, AA, AB, AD, AE, AF, AG, AH, AJ, and AK, in that order. Thus STL would be the first to enter AA and would be in AH, AJ and AK after shift-in.

Also needed to accomplish shift-in are the editing waveform and clock pulse from the Video Track Programmer. In logic equation form, the shift-in operation is:

1. $\overline{KT6}$ (Msg. line in) C (E. W.) $(\overline{MA}) \rightarrow SR_{1-3}$

Note that $\overline{KT6}$ can not be set (even for Mode B operation) until after shift-in is completed. (Again, all shift-in operations are the same for the beginning of every mode.) There is a slight difference when a shift-in occurs in the middle of the missed-approach operation. Refer to paragraph 1. 7. 4. 2. 2. 5. 2. 3, Step 2.

1. 7. 4. 2. 2. 5. 2. 2 MODE A OPERATION - Mode A operation begins in state (00) (End of Compute)

1. Shift-in occurs when the clock and the editing waveform are sent by the Video Track Programmer as described above:

   $\overline{KT6}$ (Msg. line in) C (E. W.) $(\overline{MA}) \rightarrow SR_{1-3}$

2. Shift-out would occur in the same ways as shift-in:

   (SR3) $(\overline{KT6})$ (E. W.) $\rightarrow$ VTP Msg. Line Out
   (Note that this output is ignored by VTP during shift-in)

3. At the Start Compute Gate from the VTP, ETF is shifted in parallel to the ETF register:

   C (S. C.) $(AA_{1-7}, AB_1) \Rightarrow AD_{1-8}$

4. KT3 will be set if a path stretch has been initiated (path stretch time $\neq$ 1's):

   C (S. C.) $(AB_4, AD_{1-3}, \neq 1\text{'s})$ $(\overline{MA}) \rightarrow KT3$

5. KT5 is set if path stretch time equals real time (this removes the path stretch from the PPDD and replaces it with ETF):

$$C\ (S.C.)\ (AB_4,\ AD_{1-3} = RCT) \rightarrow KT5$$

6. A Parity No Good signal is sent to VTP and the state is changed to (10) if the route equals all ones:

$$C\ (S.C.)\ (AG_{1-5} = 1\text{'s}) \rightarrow \text{Parity no good to VTP, to (10)}$$

7. KT7 is used to switch synchronism from C to C_2:

$$C\ (S.C.)\ (AG_{1-5} \neq 1\text{'s}) \rightarrow KT7$$

Steps 3, 4, 5, 6, and 7 all occur simultaneously.

8. Clock C_1 switches state to (01) (ETF Round), sets 50 ms Lost Aircraft Timer KT1, resets KT7, sets BL_{1-3} (route leg register) equal to one, sets DA_{1-4} (TAS leg register) to state S:

$$C_1\ (KT7)\ (AG_{1-5} \neq 1\text{'s}) \rightarrow \text{to (01) } KT1,\ KT7,\ (BL_{1-3} = 1),\ (DA_{1-4} = 1),\ (DT_{1-4} = S)$$

Mode A operation continues in state (01) called "ETF Round" (refer to step 8 above).

1. Route and profile matrices are enabled to allow settling time:

$$(01) \rightarrow \text{Route and Profile enable}$$

The route and profile are enabled in this state to allow for a settling time.

2. The STL in registers AH, AJ, and AK will be counted forward or backward, depending on the sign of ETF') by the amount of the "old rounded" ETF (ETF') to assure that the output of the STL register during "compute" will be t_f' instead of t_s (see figure 37).

$$C_2\ (\overline{KT6})(\overline{MA})(AD_{1-8} \neq 0)(AB2) \rightarrow AH,\ AJ,\ AK,\ \text{back count}$$

$$C_2\ (\overline{KT6})(\overline{MA})(AD_{1-8} \neq 0)(\overline{AB2}) \rightarrow AH,\ AJ,\ AK,\ \text{forward count}$$

Clock C_2 (.01 min) does the counting described in step 2 above; however, the counting must continue only for a length of time equivalent to ETF'.

3. ETF' (in the AD register) is counted (by 1 sec. clock C_3) back to zero (while STL preset described above is taking place):

$$C_3\ (\overline{KT6})(\overline{MA})(AD_{1-8} \pm 0) \rightarrow AD_{1-8}\ \text{back count}$$

Therefore, the ETF' in the AD register being counted back to zero causes the same ETF' to be preset into the STL register.

4. When ETF' is counted to zero, clock C_2 is inhibited:

$$(AD_{1-8} = 0)(\overline{KT6})(\overline{MA}) \rightarrow .01 \text{ min } (C_2) \text{ clamp}$$

5. The clock C_1 causes KS_{1-4} to count:

$$C_1 (KS_{1-4}) \pm (AD_{1-8}\ 0 + M_1A_1 + KT6) \rightarrow KS_{1-4} \text{ count}$$

6. When the count of KS_{1-4} equals 3, the profile generator logic will send a "start simulation gate" to Analog Computer:

$$KS_{1-4} = 3 \rightarrow \text{see route and profile logic (paragraph A).}$$

At the "start simulation gate" and clock C_1 from VTP, the following four events occur simultaneously:

7. ETF' is reinserted into the ETF register (in parallel shift):

$$\overline{MA}\ C_1\ (SSG)(AA_{1-7},\ AB_1) \rightarrow AD_{1-8}$$

8. The ETF' is cleared from the Tf register:

$$\overline{MA}\ C_1\ (SSG)\ AA_{1-7},\ \overline{AB}_{1-4}$$

9. KT4 is set if ETF' is positive:

$$C_1\ (SSG)\ AB2 \rightarrow KT4$$

10. The state is shifted to (11)

$$C_1\ (SSG) + C_1\ \overline{(KT1)} \text{ to } (11)$$

In state (11) (Compute) the aircraft flight simulation takes place (see figure 46 lines C and D).

1. Route and Profile matrices are still enabled in state (11), as well as the previous state, due to hold action by special purpose flip-flops in the Route Leg Simulator.

2. T_f seconds register is counted forward (from zero - refer to step 8 above) until the simulated aircraft is in coincidence with the real aircraft's position:

$$C_3(\overline{MA})\ (\overline{KT8})\ (\overline{KT6}) \rightarrow AA_{1-7}, \text{ Forward Count Aircraft}$$

$$\text{Coincidence Pulse} \rightarrow KT8$$

3. In counting t_f, when an "AA_{1-4} carry" signal is present (meaning a ten-second count has been accumulated by the units-of-seconds register AA_{1-4}, and AA_{1-4} has reset itself to zero), the 10's-of-seconds and minutes register will record the 10-second count. This assumes the 10's-of-seconds and minutes registers have not reached their maximum count of 9 minutes 60 seconds:

$$C_3\ (AA_{1-4}\ \text{carry})\ (AA_{5-7}\ AB_{1-4} \pm 9\ \text{min. } 60\ \text{sec.}) \rightarrow AA_{5-7},\ AB_{1-4}\ \text{count}$$

4. The modified (by ETF') STL is counted backward by C_2 at the beginning of the simulated flight. At the point where the count is equal to RCT, pulse t_f' is produced:

$$C_2\ (KT1) \rightarrow AH,\ AJ,\ AK\ \text{backward count}$$

The ETF counter (actually correction in ETF) will count between the aircraft coincidence pulse and the t_f' pulse.

5. Assuming the Aircraft Coincidence pulse occurs before the t_f' pulse, ETF will begin to count (from ETF' since ETF' was set into the register in the previous state). ETF will count forward (through zero, the count will reverse and count forward - note Aircraft Coincidence $\rightarrow$ KT8):

$$(C_4)(\overline{MA})(KT8)(KT4)(\overline{KT7})(KT1) \rightarrow AD_{1-8}\ \text{forward count}$$

$$(C_4)(MA)(KT8)(\overline{KT4})(KT7)(KT1) \rightarrow AD_{1-8}\ \text{backward count}$$

6. If t_f' occurs before aircraft coincidence, an operation similar to step 5 occurs. In this case, ETF will begin to count in the direction opposite to that described in step 5 above. (Note that KT8 remains reset. Note that t_f' pulse sets KT7):

$$C_2\ (AH,\ AJ,\ AK, = RCT) \rightarrow KT7$$

$$(C_4)(\overline{MA})(\overline{KT8})(KT4)(KT7)(KT1) \rightarrow AD_{1-8}\ \text{backward count}$$

$$(C_4)(\overline{MA})(\overline{KT8})(\overline{KT4})(KT7)(KT1) \rightarrow AD_{1-8}\ \text{forward count}$$

To reverse the ETF count at zero and make it count forward (as described in step 5 above), the ETF sign flip-flop is set or reset depending on whether the aircraft coincidence pulse or the t_f' pulse arrived first.

7. The backward count in step 5 (aircraft coincidence pulse is first) is reversed by setting KT4:

$$(KT8)\ C_4\ (AD_{1-8} = 1)\ (KT7)\ KT4) \rightarrow \overline{KT4}$$

8. The backward count in step 6 (t_f' is first) is reversed by resetting KT4:

$$(\overline{KT8})\ C_4\ (AD_{1-8} = 1)\ (KT7)\ (KT4) \rightarrow \overline{KT4}$$

In step 7 or 8 above, changing the state will not affect the counting direction of the ETF until the next clock pulse after the count-of-one clock pulse. Therefore, the direction of count is actually being changed at the count of zero.

9. When both the aircraft coincidence pulse and the t_f' pulse have occurred, the last aircraft timer is reset, the altitude register is reset, AG_1, AH_6, KS_{1-4}, are reset and the state is changed to (10) (Digitize and Display Makeup):

$$C_2\ (KT8)(KT7)(MA)(KT6) \rightarrow KT1,\ AH, AJ, AK, AG1, AH6, KS_{1-4}\ \text{to}\ (10)$$

10. In the event that the last Aircraft Timer (KT1) reset before the operations through step 9 above were completed, X's are put in display error register, altitude is reset, AG1 is reset, KT7 and AH6 are set, KS_{1-4} is reset, and the computer state is switched to (10):

$$C_2\ (\overline{KT1})(\overline{MA})(\overline{KT6}) \rightarrow (\text{X's in D. E.}),\ \overline{AH}, \overline{AJ}, \overline{AK}, AG1,$$
$$KT7,\ AH6,\ KS_{1-4},\ \text{to}\ (10)$$

11. Also, when KT1 reset in caused KT3 to be set (simultaneously with or before step 10 above) which results in a "data no good" signal to VTP (C_2 KT1 KT3):

KT3 → Data No Good gate to VTP (Error Gate)

In state (10) (Digitize and # Display Makeup) (see step 9 above), the computed information is put in proper order to be used.

1. KT7 is used to resync the operation with C (the VTP clock):

$$C(KT7) \rightarrow \overline{KT7}$$

2. The counting of KS_{1-4} will be used to control the operations for display makeup:

$$(\overline{SP})\ C\ (\overline{KT7})\ (\overline{MA}) \rightarrow KS_{1-4}\ \text{count}$$

3. The altitude will be digitized and set into the altitude display register ($AH_{7,8}$, AJ, AK) on any count of KS_{1-4}:

$C\ (KS_{1-4} = n) \rightarrow$ set bits in altitude per digitize routine

4. Several operations occur when the count of KS_{1-4} is equal to two:

a. The "new rounded" ETF is shifted in parallel from AD_{1-8} to the readout position AG_{2-5}, AH_{1-4}:

$$C\ (KS_{1-4} = 2)\ \overline{KT6}\ (AD_{1-8},\ AH_{1-4})$$

KT4 (which represents the sign of ETF) will control whether AH5 is set or not:

$$C\ (KS_{1-4} = 2)\ KT4\ (\overline{KT6}) \rightarrow AH5$$

b. Since the readout of time to fly will be in minutes, tens-of-seconds, and fives-of-seconds, the three least significant bits of time to fly will be "rounded off". A count of 8 or 9 seconds will be counted as one more count in the tens-of-seconds register:

$$C\ (KS_{1-4} = 2)\ (AA_{1-4} = 8, 9) \rightarrow AA,\ AB \text{ count}$$

(Note - a count of 7, 6 or 5 seconds will be counted as "one fives-of-seconds". Four seconds or less is counted as zero fives-of seconds.)

c. The leader control (AK4) is set if a path stretch is needed but has not been initiated:

$$C\ (KS_{1-4} = 2)\ \overline{KT3}\ (AD_{1-8} > +10)$$

This means that the leader is brightened to indicate that the aircraft is more than 10 seconds ahead of schedule and should have a path stretch to put it back on schedule.

d. KT5 is reset if ETF is less than 10 seconds:

$$C\ (KS_{1-4} = 2)\ (AD_{1-8} < 10) \rightarrow \overline{KT5}$$

(Note - steps a, b, c and d above occur simultaneously.)

5. During the time that $KS_{1-4} = 4$, the following steps occur simultaneously:

a. The t_f rounding is continued.
If $t_f = 9$ count one:

$$C\ (KS_{1-4} = 4)\ (AA_{1-4} = 9) \rightarrow AA,\ AB \text{ count}$$

b. The "Data Ignore" bit (AG1) is set if KT3 is reset or KT5 is set, e. g., if the last aircraft timer has reset or if a path stretch is needed but has not been initiated, the data is ignored:

$$C\ (KS_{1-4} = 4)\ \overline{KT6}\ (\overline{KT3} + KT5) \rightarrow AG1$$

c. If a path stretch is available and no X's are in the display, (e. g., no path stretch will be available if the lost aircraft timer has caused X's to be displayed) the path stretch instruction is shifted in parallel into the AD, AE, and AF register:

$C\ (KS_{1-4} = 4)\ (KT6)\ (AH6)$ (Path Stretch Available) (Path Stretch Initiation)$\rightarrow$AD, AE, AF

d. If a path stretch is not available, the ETF is shifted in parallel into the display error register (see step c above):

$C(KS_{1-4} = 4)(\overline{KT6})(\overline{AH6})(\overline{\text{P.S. Available}})(AD_{1-8})\rightarrow AD, AE, AF$

$C(KS_{1-4} = 4)(\overline{KT6})(\overline{AH6})(\overline{\text{P.S. Available}})\ KT4\rightarrow E$ in DE

$C(KS_{1-4} = 4)(\overline{KT6})(\overline{AH6})(\overline{\text{P.S. Available}})\ KT4\rightarrow L$ in DE

Also the leader control is reset:

$C\ (KS_{1-4} = 4)(\overline{KT6})(\overline{AH6})(\overline{\text{P.S. Available}})\ \overline{KT4}\rightarrow\overline{AK4}$

This assumes that X's were not in the display error register.

e. T_f rounding is completed by transferring the state of AA_1 (the fives-of-seconds count) to AA_4:

$C\ (KS_{1-4} = 6)\ AA_1 \rightarrow AA_4$

$C\ (KS_{1-4} = 6)\ \overline{AA}_1 \rightarrow \overline{AA}_4$

f. When KS_{1-4} is equal to 15, the state is changed to (00) and the following are reset: $\overline{KT8}$, $\overline{DG}_{1-8}$, $\overline{DH}_{1-4}$, $\overline{KT3}$, $\overline{KT4}$, $\overline{KT6}$, $\overline{BL}_{1-3}$:

$C\ (KS_{1-4} = 15)\rightarrow$ to (00), $\overline{KT8}$, $\overline{DG}_{1-8}$, $\overline{DH}_{1-4}$, $\overline{KT3}$, $\overline{KT4}$, $\overline{KT6}$, $\overline{BL}_{1-3}$

In state (00) End of Compute, the shifting out takes place.

1. At the arrival of the editing waveform, the data is shifted out serially:

$(SR3)\ \overline{KT6}$ (E. W.)$\rightarrow$VTP Message Line out

(Note - this occurs simultaneously with shift-in. Refer to paragraph 1. 7. 4. 2. 2. 5. 2. 1)

1. 7. 4. 2. 2. 5. 2. 3 MODE B OPERATION - Mode B operation begins in exactly the same way as the other three operations. For shift-in operation refer to paragraph 1. 7. 4. 2. 2. 5. 2. 1. The main difference between Mode B and Mode A operation is that no ETF is computed during Mode B.

Mode B operation begins in state (00) (End of Compute). The operation will be almost the same as for Mode A in the (00) state. The steps are not repeated here, but may be observed by referring to paragraph 1. 7. 4. 2. 2. 5. 2. 2 for the seven steps listed under state (00). Note that Mode B shift-out will be different than for Mode A (step 2 of state (00), in paragraph 1. 7. 4. 2. 2. 5. 2. 2.)

State (01) for Mode B will be the same as for Mode A with the following exceptions:

1. ETF Rounding will not take place (ETF is not used in Mode B). Therefore, steps 2, 3 and 4 are omitted in the normal Mode A operation (refer to state 01 in paragraph 1. 7. 4. 2. 2. 5. 2. 2).

2. Step 4 listed above (clamping of clock C_2) is a necessary operation and is performed as follows:

$$KT6 + (MA) \rightarrow .01 \text{ min. } (C_2) \text{ clamp}$$

In state (11) (Compute) the operation is very similar to Mode A operation. In Mode B, the t_s pulse will be produced instead of the t_f' pulse, since ETF rounding is not performed in Mode B (see state 01):

1. T_f is counted forward:

$$C_3\ (\overline{MA})\ (\overline{KT7})\ (KT6) \rightarrow AA_{1-7} \text{ forward count}$$

$$C_3\ AA_{1-4} \text{ carry})\ (AA_{5-7},\ AB_{1-4} \pm 9 \text{ min. } 60 \text{ sec.}) \rightarrow AA_{5-7},\ AB_{1-4} \text{ count}$$

(The above equation is the same as for Mode A)

2. ETF will be counted as in Mode A, but this information will be ignored.

3. The backward count of AH, AJ, and AK produces t_s instead of t_f':

$$C_2\ (KT1) \rightarrow AH,\ AJ,\ AK \text{ backward count}$$

(Same as for Mode A)

4. When the STL = RCT, the following are reset; Lost Aircraft Timer, KT1, Altitude, N-S, E-W, KS_{1-4}, and the state is switched to (10):

$$C_2\ (AH,\ AJ,\ AK = RCT) \rightarrow KT7 \text{ (same as for Mode A)}$$

$$C_2\ (MA)\ (KT6)\ (KT7)\ (KT1) \rightarrow KT1, \text{ reset alt., N-S, E-W, } KS_{1-4}, \text{ to } (10)$$

Other operations (including "Data No Good" for reset KT1 before count is completed) are the same as for Mode A, state (11).

The operation in state (10) (Digitize and Display) is the same as for Mode A. One of the steps is performed by a different equation as follows:

1. Bits are set in the N-S and E-W by the digitize routine:

$$C\ (KS_{1-4} = n)\ KT6 \rightarrow \text{set bits in N-S and E-W per digitize routine}$$

As in Mode A, the state is now shifted to (00).

In state (00) the Mode B shift- out takes place serially as follows:

1. C (SR1) KT6 (E. W.) → SR3

2. C (SR3) KT6 (E. W.) → SR2

3. (SR2) KT6 (E. W.) → VTP Message Line Out

1.7.4.2.2.5.3 ROUTE GENERATOR - The digital portion of the route generator is primarily involved in certain coordination timing functions associated with determining the appropriate code-block information to be used in the route generator simulation and in determining when leg-update information should be provided. The operation of this portion is basically as follows: A counter is preset to the leg length read from the route constant store at the beginning of the simulation. This will be the leg length of the first leg of the route. This leg length is set into the counter and it is counted backward at a constant rate. The angle information being provided by the route and profile store assembly is set into the digital-to-analog converter and supplied as leg angle volts to the route generator and aircraft location detector. When the leg length counter reaches zero, the angle information is parallel set into this same register. Also, the leg number register is immediately updated so that a new leg is selected on the route and profile store assembly. The route and profile store assembly also provides a direction of turn indication and the angle information stored on the counter is now started counting toward the new angle. This system provides the corner rounding capability. The angle count is carried on until a count on this register equals the new angle, thus indicating that the end of turn is reached. During this turn phase, the angle information provided to the route generator has been the angle information on the counter. At the end of the turn, the system reverts to the original state. The leg length for the next leg is parallel set into the counter and the countdown is begun, the angle data is now taken from the route and profile store information.

1.7.4.2.2.5.4 SPECIAL PROBLEMS - The object of the special problem mode of operation is to provide an internal self-check for the Analog Computer. Special

problem operation can be in Mode A or Mode B as controlled by the VTP. The operation begins in state (00).

At the "start compute gate", Route, Profile and STL are modified to the special problem as determined by the special problem count:

$$C\ (S.C.)\ (\text{1st Spec. Prob.}) \rightarrow SP_{1-2}\ \text{count}$$

$$C\ (S.C.)\ (\text{Spec. Prob.})\ (SP_{1-2} = 1) \rightarrow \text{modify \#1}$$

$$C\ (S.C.)\ (\text{Spec. Prob.})\ (SP_{1-2} = 2) \rightarrow \text{modify \#2}$$

$$C\ (S.C.)(\text{Spec. Prob.})\ (SP_{1-2} = 3) \rightarrow \text{modify \#3}$$

Note that the operation proceeds as a normal Mode A or Mode B (see previous description) and the function of the special problem count is merely to provide the input data (route, profile, etc.) for a fictitious aircraft. In states (01) and (11), the operation is exactly like a Mode A or Mode B operation. A check for an erroneous computation is made in state (10) (Digitize and Display Makeup).

An error signal from the computation will cause an error signal to be sent to the VTP:

$$C\ (\overline{KT7})\ (S.P.)\ (\text{Error}) \rightarrow \text{Error Signal}$$

The error signal will illuminate a red light on the chassis, indicating that a problem has been missed.

<u>Special functions in State (00)</u>

State (00) could be called the "steady state" of the Analog Computer since it is the state used for the beginning and end of each operation.

State (00) is also used for Tracker assignment or Mode B print:

The D/A Enable Gate enables the D/A converters

(D/A Enable G)→D/A enable

1.7.4.2.2.5.5 <u>PATH STRETCH</u> - A path stretch is recommended by the Analog Computer to the controller when an aircraft gets ahead of schedule by a certain time. This time is 11.9 seconds for aircraft traveling slower than 210 knots and 19.6 seconds for aircraft traveling faster than 210 knots.

An aircraft making a path-stretch maneuver flies a path composed of the two legs of an isosceles triangle. The two legs are at an angle of 45 to 60 degrees with the route leg. Further, it is assumed that the aircraft is flying directly over the

route leg and is not off-course.

The Analog Computer must decide whether the path stretch can be completed before the aircraft arrives at the end of the route leg which it is presently following. If the path stretch can not be completed on the present route leg, the path stretch will not be recommended until the aircraft is on a new route leg.

The object of the path stretch is to reduce as much as possible the time by which the aircraft is ahead of schedule, without making the aircraft fall behind schedule. The twenty possible path-stretch recommendations are listed below. Note that an aircraft traveling faster than 210 knots must have a slower rate of turn.

The path stretch consists of three turns: a number (either 4 or 6) to represent 45° or 60°, the letter "T" (representing "turn"), and another number which represents the length of time to be flown on each leg of the isosceles triangle.

For speeds exceeding 210 knots (use 1-1/2° per second turns)

ETF Value in Sec.	Path Stretch Command
19.6 - 25.3	4T0
25.4 - 31.2	4T1
31.3 - 37.1	4T2
37.2 - 37.6	4T3
37.7 - 47.6	6T1
47.7 - 57.6	6T2
57.7 - 67.6	6T3
67.7 - 99.0	6T4

For speeds below 210 knots (use 3° per second turns)

ETF Value in Sec.	Path Stretch Command
11.9 - 17.6	4T1
17.7 - 23.5	4T2
23.6 - 29.4	4T3
29.5 - 33.8	4T4
33.9 - 43.8	6T2
43.9 - 53.8	6T3
53.9 - 63.8	6T4
63.9 - 73.8	6T5
73.9 - 83.8	6T6
83.9 - 93.8	6T7
93.9 - 99.0	6T8

1.7.4.2.2.5.6 LEADER CONTROL - Code A represents the fact that a path stretch is needed but has not be initiated. This takes place when the aircraft gets more than 10 seconds ahead of schedule. The result of Code A is to brighten the leader.

Code B represents the fact that one facility is ready to transfer control of a particular aircraft to another facility. The result of Code B is to serrate (or make dotted) the leader.

Code C represents the fact that the trackers are in automatic-coast operation. The result of Code C is to put a full-length bar across the top of the format.

Code D represents the fact that the trackers are in manual-coast operation. The result of Code D is to put a half-length bar across the top of the format.

1.7.4.2.2.5.7 MISSED APPROACH - In this computation, the Video Track Programmer (VTP) uses the Analog Computer to tentatively select a new landing sequence number for a missed-approach aircraft as a function of various missed-approach routes and profiles.

There are two phases to the missed approach computation. During the first phase, the Analog Computer determines an estimated time of landing (ETL) for the missed approach route and profile given by the VTP. During the second phase, the VTP sends the Analog Computer a series of STL's (starting with the aircraft's flight plan STL) corresponding to successively later landing-sequence numbers.

The Analog Computer uses a subtraction process to determine the first landing-sequence number which has an STL later than that of the computed ETL. The VTP will cause the Analog Computer to perform phase one followed by Phase two for each of the three missed-approach routes associated with a given runway.

PHASE ONE

The VTP begins the missed approach operation by putting the Analog Computer in state (00) (End of Compute).

Shift-in operation, state (00), Phase one, is identical with that specified for Mode A or Mode B operation:

1. $\overline{\text{KT6}}$ Msg. Line In (C) ($MA \rightarrow SR_{1-3}$)

Note that KT6 can not be set until after shift-in and MA can't exist until after shift-in. Thus all shift-in operations are the same.

However, only the route and profile are utilized by the Analog Computer. All other data shifted in by the VTP will be ignored. The editing waveform (from

VTP) is the same as it would be in pure Mode A or Mode B operation (see step 1 listed above).

After the data is shifted in, the VTP begins Phase one of the operation by sending a Start Compute Gate to the Analog Computer. This gate in coincidence with the clock pulse C (from VTP 144-kc fixed clock) will cause:

2. ETF to be shifted (in parallel) from AA_{1-7}, AB_1) $\Rightarrow$ AD_{1-8} (this information is ignored by the Analog Computer).

3. KT5 to be set if path stretch time $\cong$ RCT:

$$C\ (SC)\ (AB_4,\ AD_{1-3} = RCT) \rightarrow KT5$$ (ignored by Analog Computer)

4. A Parity No Good (Route = 1's) signal to the VTP and a [redacted] in state to (01) (ETF Round):

$$C\ (SC)\ (AG_{1-5} = 1's) \rightarrow \text{Parity no good to VTP, to (01)}$$

5. KT7 to be set (used to sync onto a different clock pulse) if parity is good:

$$C\ (SC)\ (AG_{1-5} \pm 1's) \rightarrow KT7$$

The four steps listed immediately above all occur simultaneously.

6. If parity is good, Lost Aircraft [redacted] KT1 is set, KT7 is reset, and the state of the Analog Computer shifts to (01):

$$C_1\ (KT7)\ (AG_{1-5} \pm 1's) \rightarrow \text{to (01), KT1, KT7}$$

In state (01) (ETF Round) (refer to step 5 above), the following will occur:

1. The missed-approach route and profile are enabled to allow settling time before state (11):

(01) Route and Profile enable.

2. In Mode B, the .01 min. clock is clamped:

$$KT6 + (M.A.) \rightarrow .01 \text{ min. } (C_2) \text{ clamp.}$$

3. Clock Pulse C_1, causes scalor KS_{1-4} to count:

$$C_1\ (KS_{1-4} \pm 3) \rightarrow KS_{1-4} \text{ count.}$$

3a. This sends a gate T_1 to the analog portion as long as the count of KS_{1-4} is less than three:

$$(KS_{1-4} \pm 3) \rightarrow T_1 \text{ gate to the analog portion.}$$

3b. While the count equals three, a gate T_2 is sent to the analog portion:

$(KS_{1-4} = 3) \rightarrow T_2$ gate to analog portion.

At a time equal to or later than gate T_2 (in Mode B or missed approach), the analog portion will send a Change State Gate CSG' to the digital control and timing circuits.

4. CSG' from the analog portion causes a change state gate to be produced:

$$(CSG')(KT6 + MA) + (CSG')(AD_{1-8} = 0) \rightarrow CSG$$

The change state gate causes the following three steps to occur simultaneously:

5. KT4 is set if AB2 is set:

C_1 (CSG) AB2 $\rightarrow$ KT4 (ignored by Analog Computer)

6. Real Clock Time is inserted (by parallel shift) into the ETF and T_f registers:

C_1 (CSG) (MA) (RCT) $\Rightarrow AA_{1-7}, AB_{1-4}, AD_{1-8}$

7. The state is changed to (11):

C_1 (CSG) $\rightarrow$ to (11).

In state (11) (Compute) (refer to step 7 above), the following will occur: (Note the simulated flight is now in progress.)

1. The missed-approach route and profile are enabled:

(11) $\rightarrow$ Route and Profile enable

2. The .01 minute clock C_2 will count STL (fictitious) backwards assuming Lost Aircraft Timer has not been reset:

C_2 (KT1) $\rightarrow$ AH, AJ, AK back count (ignored by Analog Computer)

3. If STL equals RCT, KT7 is set:

C_2 (AH, AJ, AK = RCT) $\rightarrow$ KT7 (ignored by Analog Computer)

4. If aircraft coincidence occurs and AD_{1-8} equals 1's, KT4 may be set or reset depending on KT7:

$(ATC)\ C_4\ (AD_{1-8} = 1)\ (KT7)\ (KT4) \rightarrow \overline{KT4}$

$(AC)\ C_4\ (AD_{1-8} = 1)\ (\overline{KT7})\ (\overline{KT4}) \rightarrow KT4$ (ignored by Analog Computer)

5. C_2 clock counts AA, AB and AD register during simulated flight forwards from RCT to determine calculated ETL (for missed-approach route):

$$C_2\,(MA) \rightarrow AA,\ AB,\ AD \text{ forward count}$$

6. Upon aircraft coincidence in simulated flight the state is changed to (10) (assuming Lost Aircraft Timer did not reset):

$$C_2\,(AC)\,(MA)\,KT1 \rightarrow \text{to } (10)\ \overline{KT1},\ KT7$$

Note that the AA, AB, AD register now reads the calculated ETL of the aircraft.

7. If the Lost Aircraft Timer did reset before Aircraft coincidence, a data no-good signal is sent to the VTP and state is changed to (10):

$$C_2\,KT1 \rightarrow KT3$$

$$KT3 \rightarrow \text{error gate to VTP}$$

$$C_2\,(KT3)\,(MA + KT6) \rightarrow \text{to } (10),\ KT7,\ \overline{KS_{1-4}}$$

In state (10) (see step 6 above), the following occurs:

1. KT7 is used to resync on clock pulse C:

$$C\,(KT7) \rightarrow \overline{KT7}$$

2. The state is shifted to (00) and several other circuits are set or reset for later use on the second clock pulse:

$$C\,(\overline{KT7})\,(MA) \rightarrow (00),\ \overline{KT8},\ \overline{DG_{1-8}},\ \overline{DH_{1-4}},\ \overline{BL_{1-3}},\ \overline{KT3},\ \overline{KT4},\ \overline{KT6},\ KT5$$

PHASE TWO

The Analog Computer now operates in state (00) again. This constitutes the beginning of Phase two. Phase two will be completed in state (00) by using the calculated ETL (determined in Phase one) to compare with successive STL's, chosen by VTP, beginning with the aircraft's flight plan STL. Phase two ends when the Analog Computer notifies the VTP that the VTP has just chosen a STL later than the calculated ETL.

The STL proposed to Analog Computer by the VTP just before the notification mentioned above will be the time slot displayed on the PPDD as the optimum landing time slot for that given missed-approach route. The three optimum time slots for three missed-approach routes are displayed on the PPDD as the center column of boxes at the bottom of the display.

Phase two operation of the Analog Computer in state (00) is as follows:

1. During Phase two shift-in, MA gate from VTP causes a proposed STL to be shifted into SR3:

$$(\text{Msg. line in})\ (C)\ (\text{E. W.})\ (\text{M. A. Sub.}) \rightarrow \text{SR3}$$

2. When KT6 is reset by the VTP for Phase two shift-in, SR3 will try to shift out to the VTP:

$$\text{SR3}\ (\overline{\text{KT6}})\ (\text{E. W.}) \rightarrow \text{VTP Msg. line out (ignored by VTP and Analog Computer)}$$

3. The subtraction gate (Sub. G.) and clock (when STL ± ETL) sets KT3:

$$C\ (\text{Sub. G.})\ (AH_{5-8},\ AJ,\ AK,\ \pm AA,\ AB,\ AD) \rightarrow \text{KT3}$$

KT3 and KT4 will be used to determine when the VTP has proposed a STL later than the calculated ETL.

4. The subtraction gate from the VTP (Sub. G.) will cause the proposed STL to count forward:

$$C\ (\text{Sub. G.}) \rightarrow \text{AH, AJ, AK forward count.}$$

Note that (Sub. G.) lasts for only two minutes in analog time.

5. If equality between ETL and STL is reached before the end of the Sub. Gate, KT4 is set and KT3 is reset:

$$C\ (AH_{5-8},\ AJ_{1-7},\ AK_{1-4},\ = AA,\ AB,\ AD)\ (\text{Sub. Gate} \rightarrow \text{KT4},\ \overline{\text{KT3}}$$

6. However, if equality is not reached between ETL and STL before the end of the Sub. Gate, KT4 remains reset and KT3 is reset:

$$C\ (\text{KT3})\ (\overline{\text{Sub. G.}}) \rightarrow \text{KT3}$$

Note that KT3 is reset (during Phase two) every time the Sub. Gate ends or equality between STL and ETL is reached while the Sub. Gate is still on. As long as Phase two continues (e. g., as long as no ETL sign change described below is sent to VTP), a new proposed STL will be shifted into SR3 at the end of the Sub. Gate for subtraction with the ETL.

7. After one or more Phase two subtractions have occurred in which equality between ETL and STL was reached (e. g., KT4 was set and remained set), and "STL sign change" will be sent to VTP when at the end of the Sub. Gate, KT3 remains set (indicating equality has been lost, step 5 above):

$$KT3\ (\overline{Sub.\ G.})\ KT4 \rightarrow \text{"STL sign change" to VTP}$$

8. KT3 and KT4 are reset under the same condition (plus a clock pulse) necessary to give "STL sign change" (step 7 above):

$$C\ (KT3)\ (\overline{Sub.\ G.})\ KT4 \rightarrow \overline{KT3},\ \overline{KT4}$$

Steps 7 and 8 above end Phase two of the missed-approach sequence for a given missed-approach route. This means that during Phase two, the VTP proposed STL's were at first earlier than the calculated ETL. Finally (step 7 above) the VTP proposed a STL that was later than ETL. The VTP was then notified of the STL sign change by the Analog Computer (step 7). The VTP then presents in the center optimum on the PPDD the STL proposed immediately before the last STL which caused the STL sign change. Thus, the optimum time slot presented on the PPDD for a given MA route will be as close as possible to the calculated ETL while still remaining earlier than ETL. This gives the advantage of using a path stretch, if necessary, to reduce the difference between ETL and STL rather than having the pilot applying more power to catch up and make good on his STL.

1.7.4.2.2.6 POWER SUPPLIES

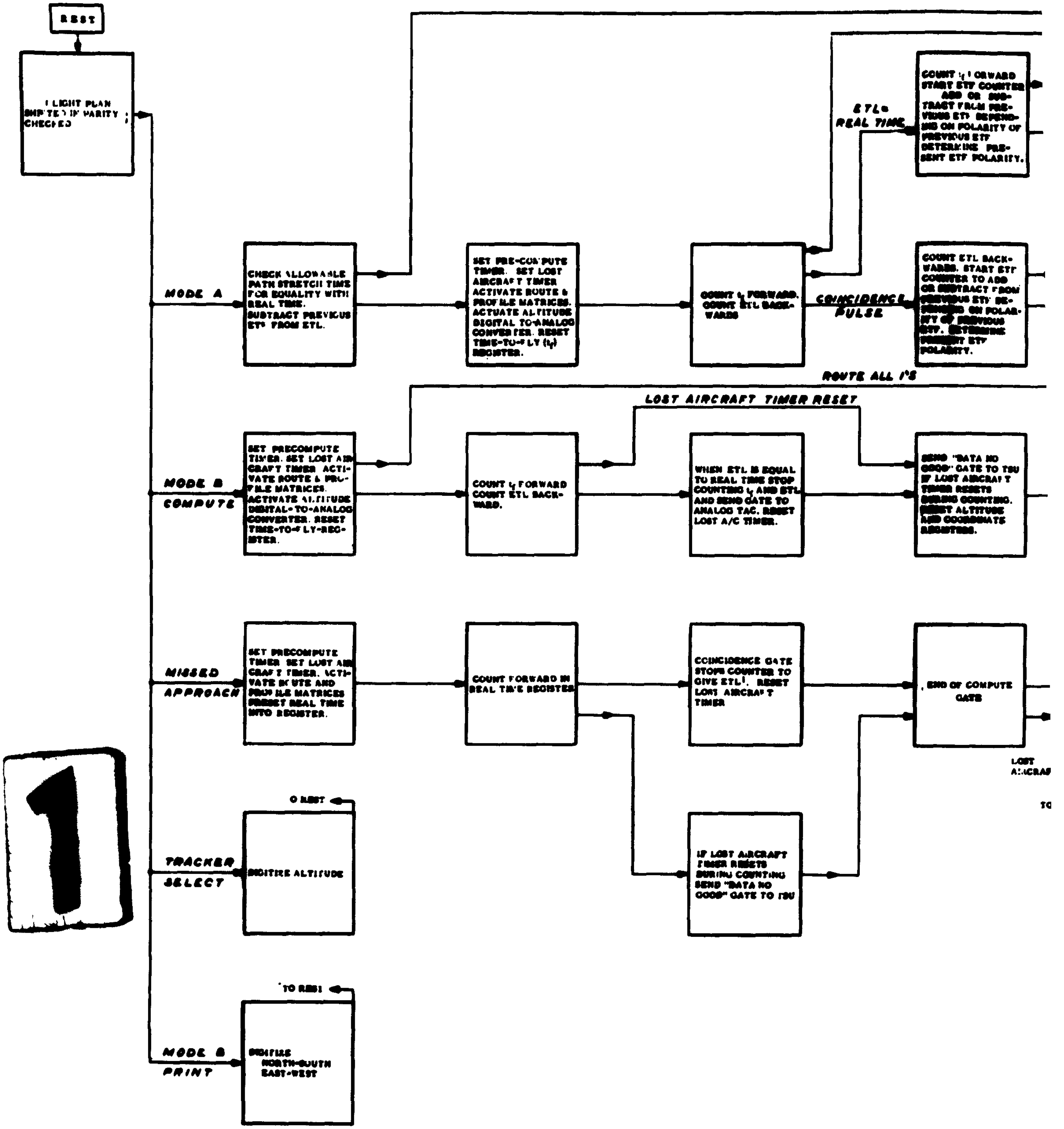
1.7.4.2.2.6.1 Transistor regulated supplies were solicited for reasons given in paragraph 1.1.6.3.1 for the Conditioner-Generator Unit.

1.7.4.2.2.6.2 Power supply units were purchased in modular sizes compatible with system packaging. Requirements for +18 volts dc and -18 volts dc were eliminated by placing the load on 24-volt d-c units. Specifications were written, bids were advertised, and contracts let for the following power supplies:

	Volts DC	*Regulation	Current	Specification
1.	45 vdc	±0.05%	1 amp	TIC 1089
2.	24 vdc	±3.0%	7 amp	TIC 1087
3.	24 vdc	±0.5%	0.5 amp	TIC 1086
4.	12 vdc	±3.0%	2 amp	TIC 1083
5.	100 vdc	±0.5%	1 amp	TIC 1090
6.	100 vdc	±0.01%	0.6 amp	TIC 1076
7.	18 vdc	±3%	2 amp	TIC 1088**

* No load to full load and ±10% of nominal input

** This specification was cancelled after delivery of two prototype units at which time -24 volts dc was utilized in place of 18 volts dc.



RESET
CHECK ALLOWABLE PATH STRETCH TIME FOR EQUALITY WITH REAL TIME. SUBTRACT PREVIOUS ETF FROM ETL.
SET PRE-COMPUTE TIMER. SET LOST AIRCRAFT TIMER. ACTIVATE ROUTE & PROFILE MATRICES. ACTUATE ALTITUDE DIGITAL TO-ANALOG CONVERTER. RESET TIME-TO-FLY (t_f) REGISTER.
COUNT t_f FORWARD. COUNT ETL BACKWARDS
ETL = REAL TIME
COINCIDENCE PULSE
ROUTE ALL 1'S
LOST AIRCRAFT TIMER RESET
MODE A
MODE B COMPUTE
MISSED APPROACH
TRACKER SELECT
MODE B PRINT
SET PRECOMPUTE TIMER. SET LOST AIRCRAFT TIMER. ACTIVATE ROUTE & PROFILE MATRICES. ACTIVATE ALTITUDE DIGITAL-TO-ANALOG CONVERTER. RESET TIME-TO-FLY-REGISTER.
COUNT t_f FORWARD COUNT ETL BACKWARD.
WHEN ETL IS EQUAL TO REAL TIME STOP COUNTING t_f AND ETL AND SEND GATE TO ANALOG TAC. RESET LOST A/C TIMER.
SET PRECOMPUTE TIMER SET LOST AIRCRAFT TIMER. ACTIVATE ROUTE AND PROFILE MATRICES RESET REAL TIME INTO REGISTER.
COUNT FORWARD IN REAL TIME REGISTER
COINCIDENCE GATE STOPS COUNTER TO GIVE ETL'. RESET LOST AIRCRAFT TIMER
END OF COMPUTE GATE
IF LOST AIRCRAFT TIMER RESETS DURING COUNTING SEND "DATA NO GOOD" GATE TO TSU
DIGITIZE ALTITUDE
TO RESET
DIGITIZE NORTH-SOUTH EAST-WEST
LOST AIRCRAF
TO
1

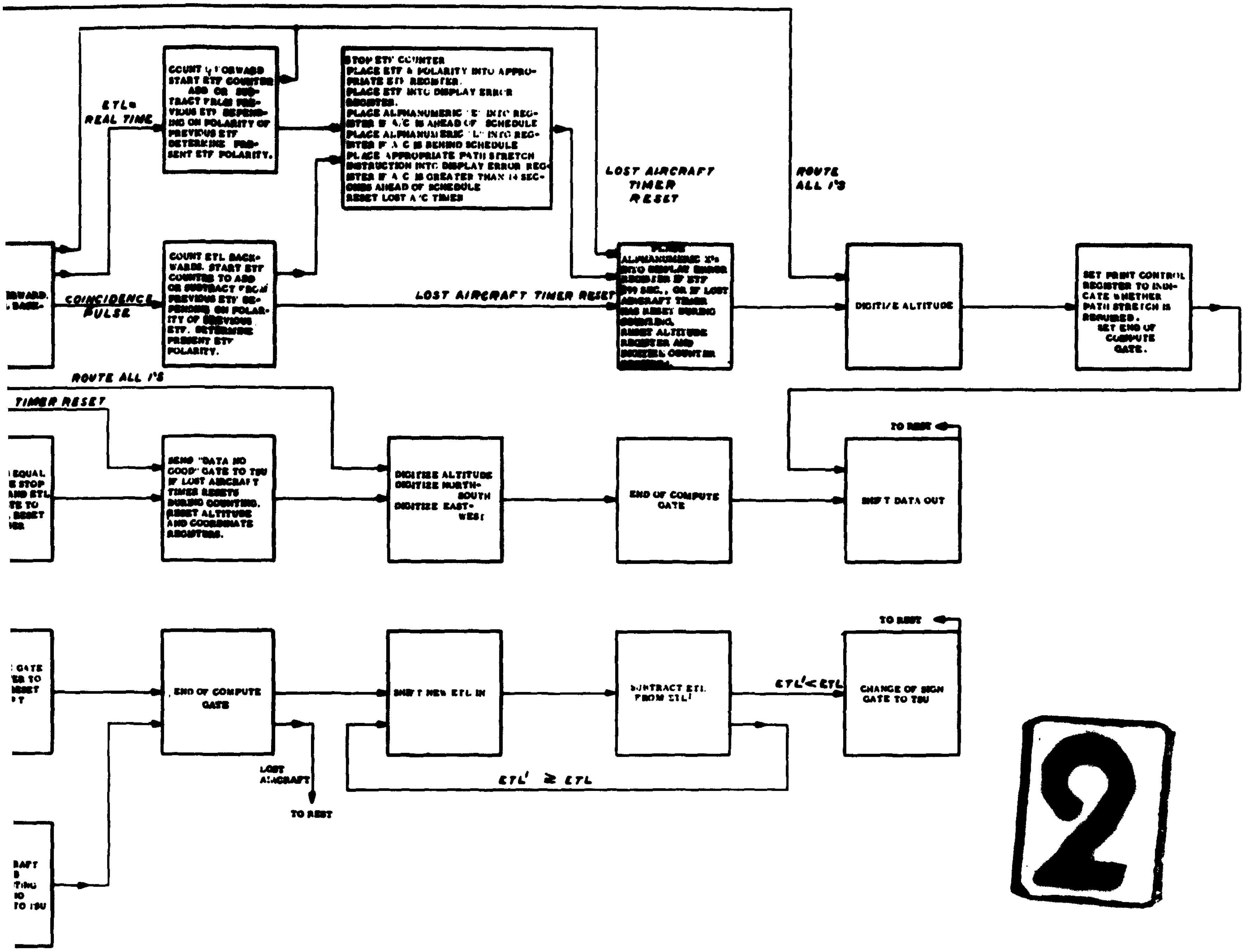


Figure 51. Analog Computer, Digital Section, Block Diagram

1.7.4.2.2.6.3 Power supply chassis units for the Analog Computer had not been fabricated during the Phase A program. Cancellation of the work prevented completion of the power supply designs. Cancellation of some power supply units with suppliers resulted.

1.7.4.2.2.6.4 The proposed final design included all considerations outlined in paragraphs 1.1.6.3.3 and 1.1.6.3.4

1.7.4.3 ENGINEERING CHANGES

1.7.4.3.1 RAPID PRINT-UP - Early in the development of the equipments, it became desirable to be able to print all information on all the aircraft within a very short time; approximately 100 milliseconds. Since the Analog Computer required 3 seconds to compute the information on all of the fifty aircraft, it was necessary to devise an interim store for the information on error in time to fly, circle coordinates, etc. It was decided that it would be far better to store this in digital form rather than in analog form, since analog storage is subject to drift for these periods of time. Therefore, it became necessary to add functions for converting analog information to digital form during computation and for converting from digital form back to analog during the print time.

1.7.4.3.2 EXPANDED ROUTE REQUIREMENT - It was initially planned to use seven inbound routes for computation purposes, however, on receipt of Issue 2 of GPL Specification 10000-523, the requirement was called out as 20 inbound routes. As a result of this, it was necessary to expand the route storage capability. Initially, there was some concern about the capability of storing this in the network potentiometric system. The taper-pin storage system, however, was ultimately determined to be a more satisfactory approach. This was partially because of the greater number of routes to be stored and the greater storage capacity requirements. This change resulted in a re-evaluation of the space available in the Analog Computer.

1.7.4.3.3 ROUTE AND PROFILE INFORMATION DELAY - The exact route and profile information required for the Computer was not received until very late in the program. This resulted in delay of the work and design effort on the route and profile portions of the Analog Computer. Eventually, a system for designing this was evolved by Tasker and this suggested to GPL. This delay caused study and evaluation work on what might be expected in the line of routes and profiles.

1.7.4.3.4 CONSIDERATION OF CHANGES (IAS, ETC.) - The first changes to be considered were the GPL changes G1, G2 and G3. These concerned changing

from the use of true air speed to the use of indicated air speed. The second change considered was to allow for independent selection of speed profiles and altitude profiles. The third change was to allow for penetration altitudes. That is, an aircraft could come in at a fixed altitude and begin its descent when it penetrated the descent pattern. Discussion of these changes was made at this time by TIC and briefly between GPL and TIC. Several memos were written on the subject and estimates were made at this time. Shortly after this, the subject was again considered and some further refinements of the speed profile considered. In particular, Howard Stokes of the FAA made a visit to TIC and there were conferences at that time between GPL/TIC and Howard Stokes. Again this subject was brought up as change G-11 and was bid as a change of scope on this basis. At that point, the matter was set aside for a period of time, although much effort was expended in determining exactly what it would take to handle the changed approach. Again this same subject arose as Addendum 4 and Addendum 4A to Engineering Requirement AMB-58-2. These changes were also bid by TIC. This latest information included some methods of path maneuvering to replace the path stretch, in addition to the change to an entirely different pattern utilizing indicated air speed and the use of penetration altitudes with independent selection of speed and altitude profiles. The final change considered was Addendum 4B and at this time a discussion was held in Washington by FAA, GPL and TIC personnel to determine what the final technique should be. It was decided at this point that these new changes should not be incorporated and that the equipment should be completed without any of the Addendum 4's in the contract.

1.7.4.3.5 TEST ROUTINES - Fairly early in the program, it was recommended by TIC that test routines be incorporated in the Computer. As a result of this, certain test routines were evaluated and methods for including these test routines were studied. Eventually, a system was arrived at which would test all the route and profile structures and also test the operation of the Analog Computer in each of the various modes of operation. This test routine involved primarily digital hardware and the analog computing section or simulator section was very little influenced. Effectively, the majority of the test routines were stored in the Video Track Programmer as additional flight plans, and the Analog Computer, with a minimum amount of test routine memory, modified these test routines to test each of the required pieces of information.

1.7.4.3.6 PATH STRETCH COMPUTATION EXPANSION - Early in the program it became necessary to provide the capability of indicating an appropriate path-stretching maneuver to delay aircraft that were significantly ahead of schedule. This was incorporated by determining when the error in time to fly exceeded a particular value and on the basis of this error and the type of aircraft an appropriate path-stretch was selected.

1.7.4.3.7 OPERATIONAL AMPLIFIER AND VCO IMPROVEMENTS - The first operational amplifier considered was of a highly simplified design utilizing four transistor stages. This design showed good temperature characteristics and utilized a 90-volt output dynamic range. Later it was determined that the frequency characteristics of this amplifier were marginal and inadequate. The first attempt to fix this was the addition of two transistor stages as a parallel amplifier in order to boost the response. However, this actually caused more frequency response and stability problems. In February 1960, an analysis of the operational amplifier by GPL and TIC determined that a new approach should be taken on the operational amplifier and a new circuit was designed taking extreme care to keep the response high and yet maintain good stability. The final amplifier had a temperature stability of approximately 5 millivolts as compared with the first amplifier's stability of approximately 2 to 3 millivolts. However, the frequency response was such that the amplifier had an open-loop unity gain at 2 mc and exhibited an approximately uniform 6 db per octave roll off from a 100 db d-c gain. This amplifier also had a wide dynamic range although, in this case, its output was limited to approximately 78 to 80 volts. The amplifier was then laid out using miniaturization techniques so each amplifier could be enclosed in a shielded can. The amplifier was capable of being mounted with four units to a single 6 x 9 inch card. In general, however, it was expected that the modules would be placed on the cards containing the critical circuits associated with the particular amplifier.

This was also a deviation from the initial approach of having a single card which was laid out for operational amplifiers only, with no provision for the associated networks.

The time-dependent variable change brought in the requirement of a voltage controlled oscillator. The initial efforts along this line were with the multivibrator type of oscillator. However, upon recommendation from GPL and consideration by TIC, other techniques were studied and evaluated. As a result of these studies, the design which was considered to be the optimum at the time of cancellation of the equipment was to use an operational amplifier integrator approach with a comparator on the output of the integrator. Preliminary data showed that the required 0.1 per cent linearity and 0.1 per cent stability could be achieved by this technique. In addition, this technique had the advantage of using standard building-block design, thus minimizing the requirement for increased design effort.

1.7.4.3.8 PATH STRETCH RESTRICTIONS - In Issue 4 of the Specification 10000-523, the following requirements were imposed on the operation of the path stretch. Path stretches were to be prohibited:

a. If the path stretch would cause the aircraft to deviate more than five statute miles from the center of the route which it is flying. The decision logic incorporated in the Analog Computer to provide this was to use the speed of the

aircraft. The networks were set up so that if the aircraft exceeded a certain speed, certain path stretches would be prohibited.

b. That a path stretch must be completed before the aircraft reaches a turn. To provide this capability, the time from the point where an aircraft should begin its turn was kept track of and path stretches were inhibited on the basis of the time from turn, so that time from turn would not exceed the time it would take to complete the path stretch.

1.7.4.3.9 DIGITAL PORTION - The following engineering changes incorporated in the analog portion of the Computer had strong influence on the digital portion of the Analog Computer. These were: 1. rapid printup, 2. expanded route requirements, 3. route and profile information delay, 4. consideration of changes, 5. test routines, 6. path stretch computation expansion, and 7. new path stretch restrictions.

1.7.5 RECOMMENDATIONS

1.7.5.1 GENERAL

1.7.5.1.1 FLIGHT PLAN TRACKING - One modification that may be of value is to utilize the system of flight plan tracking as described in the final design section. This modification would increase the accuracy of the trackers, thereby attaining greater accuracy in the computation system.

1.7.5.1.2 WIND BIAS CORRECTION - This system of operation was described in paragraph 1.7.3.1.8. This modification would take into account the changing wind conditions and actually tend to correct any errors that might be generated by the Analog Computer or any drifts in the Analog Computer. This is a fairly simple addition. However, in the case where the Analog Computer will work as a computing element independent of the Transition Computer, it is possible that the two computers might not be working on exactly the same wind data at the same time and this could cause problems at hand-over.

1.7.5.1.3 IAS SYSTEM - This possible modification was discussed briefly in paragraph 1.7.4.3.4. The modification has several major advantages and was seriously considered by the FAA, GPL and TIC. It was quoted on in several forms and a thorough engineering evaluation was made of the modification. The modification would result in the storing of the speed profile in the form of indicated airspeed rather than true airspeed. The indicated airspeed would then be converted to true airspeed by taking the altitude into account. The modifications proposed

would take advantage of the increased flexibility of this system. Essentially, there were regions of fixed, indicated airspeeds, and the aircraft could take any of these airspeeds in that region. The profile itself would merely indicate what speeds were to be used and in what regions. The domain of the regions from touchdown was independent of aircraft type. There was even consideration of a type of derandomization making use of this speed assignment information. In conjunction with this approach, the altitude profiles could now be selected independently of the speed profiles, permitting much greater flexibility of aircraft characteristics. This modification would actually ease the problem of storing speed profiles because now only a few fixed constant speed profiles need be used, and the capability of handling flexible speed versus distance profiles would not be necessary or would occur under controlled or known conditions.

1.7.5.1.4 PATH MANEUVER - This modification came up primarily in discussions although mention of it was made in GPL change G11 to Specification 10000-523. This change is concerned with various methods of correcting aircraft schedules, whether they are ahead of or behind time. There were numerous techniques discussed for causing the aircraft to be corrected when it was not properly on schedule. The gist of most of these was to create a region whereby the aircraft had a number of possible paths, each of which involved a different distance. The path which the aircraft would normally be expected to take would be the central path of the set. Thus, as the aircraft entered this region, it would be given instructions to take either the center path if it was on time, or one of the paths on either side of the center path to appropriately correct a schedule deficiency. It is possible to make up rather involved structures which would give gross corrections at an early point, refine the corrections at a later point, and then further refine the corrections as the aircraft approaches nearer to touchdown. The methods of instrumenting and indicating to the controller what has been computed varied from essentially no information given by the computer to fully automatic indication to the pilot of what is required of him via data link. The optimum of these recommendations was not really determined, and should probably be determined by simulation of the various possible systems.

1.7.5.1.5 DERANDOMIZATION - A possible modification which was considered is to incorporate in the Analog Computer the minimal capabilities for derandomizing aircraft, so that the Analog Computer can be utilized as a back up to the Transition Computer for purposes of derandomization. There were numerous methods discussed for this possibility.

One method was to make use of the major schedule adjustment by selecting an appropriate speed profile. This method is one of the more promising techniques in derandomizing aircraft, since this works as a major correction when the aircraft is in the Transition Area and can be used for fine-grain minor corrections as the aircraft approaches the final phases of the terminal approach.

The scheduling capability is, to some extent, built into the Analog Computer since basically the same rescheduling problem is encountered in the case of missed-approach aircraft. The major problem is the entry of information from the Enroute Computer (or whatever source is available) directly into the Video Track Programmer - Analog Computer system. Presumably, this could be set in manually in an emergency backup situation, and the emergency system could provide the required flexibility in handling some of the emergency situations. Perhaps this information could be directed from the Enroute Computer directly into the Video Track Programmer, thereby bypassing a faulty transition computer.

1.7.5.2 DETAILED RECOMMENDATIONS

1.7.5.2.1 AIRCRAFT LOCATION DETECTOR - Some techniques which may represent an improvement over the present aircraft location detector are the use of the cornering techniques described in paragraph 1.7.3.2.2.2. These techniques were being discussed at the time of the termination of the contract.

1.7.5.2.2 WIND PROCESSOR - It should be possible to simplify the triangle solution technique if sufficient evaluation were given to this subject. However, because this was a one-shot type of operation, it was felt that the proposed equipment would be sufficient for the evaluation program, and the evaluation of more refined techniques might well prove more costly in the long run.

1.7.5.2.3 ROUTE AND PROFILE STORE - It is possible that more convenient or simplified techniques could be determined and it is almost certain that in the case of a large production operation that other systems would become more desirable than the one selected. However, the one selected made optimum use of available off-the-shelf components and thus proved to be the most economical for this evaluation system. The technique, as described, was breadboarded in part to determine if the circuits could be designed to meet the requirements for this piece of equipment and the full-panel loading was simulated. The final conclusion was that this type of data panel is a quite feasible one and offers many desirable characteristics.

1.7.5.2.4 DIGITAL PORTION - One consideration in the digital portion of the Analog Computer is to determine whether a certain amount of time sharing between the Video Track Programmer and the Analog Computer might be possible. It may be possible to time share certain portions of the computer with certain portions of the Video Track Programmer or some combined correlation between the two systems might result in an ultimate reduction of hardware.

1.7.5.2.5 **POWER SUPPLIES**

a. Design improvements recommended in paragraph 1.1.6.4 also apply to units proposed for application to the Analog Computer.

b. Since no implementation of the Analog Computer has resulted as of this time, no further recommendations are possible.

1.7.5.2.6 **CABINET** - Recommendations for the Analog Computer cabinet are basically the same as for the Conditioner-Generator Unit (paragraph 1.1.7 through 1.1.7.4.4).

SECTION II

TESTS AND TEST RESULTS

2.1 GENERAL

This section contains a review of acceptance tests conducted at the TIC facility and also certain results of testing performed at NAFEC. The complete test program for the Tasker designed equipments included Bench Tests, Box Tests and Unit Tests (tests of equipments in groups). This section (II) is devoted to unit testing at the TIC facility as all other aforementioned tests were intermediate to System Tests.

2.1.1 SCOPE OF TESTS AT THE TIC FACILITY

The customer's decisions as to which functions should be tested at the TIC facility and which should be tested at the NAFEC facility were based on two criteria, namely, availability of associated equipment (DPC equipments or peripheral items) required for the tests and availability of time before the FAA shipment deadline. Where the testing of the functions required the presence of other parts of the DPC system being produced by other contractors, it was obvious that the function should be tested at NAFEC. The same is true where functions would require substantial peripheral equipments such as radar sets for live radar inputs, etc., that are readily available at NAFEC and relatively expensive to provide at TIC. Finally, where the FAA decision to establish a shipment deadline of December 30, 1960 permitted too little time for completion of tests and for the formal witnessing of such tests by FAA personnel, the formal testing automatically became a NAFEC function.

The final determination of functions tested at the TIC facility is regrouped in the final issue of the Unit Test 7 Specification (dated December 31, 1960), the final issue of the Unit Test 8 Specification (dated December 31, 1960), and the final issue of the PAR Console Acceptance Test (dated December 31, 1960). Each of these specifications contains a list which defines the functions to be tested at TIC and the functions to be tested at NAFEC. An exception is made with respect to those functions which were partially passed during official testing at TIC and which have since passed official testing at NAFEC. These data are included in the Unit Test 7, Unit Test 8 and PAR Console test results as applicable.

2.1.1.1 UNIT TEST 7 (See figure 52) - Tests were performed in accordance with the latest revision of the Unit Test 7 Test Specification (TIC Specification 1145) to check the compatibility of inter-unit electrical connections of the Unit Test 7 equipments, to predetermine the reliability and stability of the equipments and to demonstrate design performance of the equipments under simulated operating

conditions. The Unit Test 7 equipment group consisted of a Video Conditioner Group, a Conditioner-Generator Unit, a Tracker Control Group, two Video Tracker Units (racks) and varying numbers of Trackers.

2.1.1.2 UNIT TEST 8 - Tests were performed in accordance with the latest revision of the Unit Test 8 Test Specification (TIC Specification 1148) to check the compatibility of inter-unit electrical connections of the Unit Test 8 equipments, to predetermine the reliability and stability of the equipments and to demonstrate design performance of the equipments under simulated operating conditions. The Unit Test 8 equipment group consisted of two Tracker pools, two Tracker Control Groups, a Conditioner-Generator Unit, an Approach Display Processor, Approach Displays (Local and PAR) and a Video Track Programmer.

Message inputs from the Digital Computer of the Data Processing Central were simulated to demonstrate the capability to handle inputs and outputs to the Transition Area.

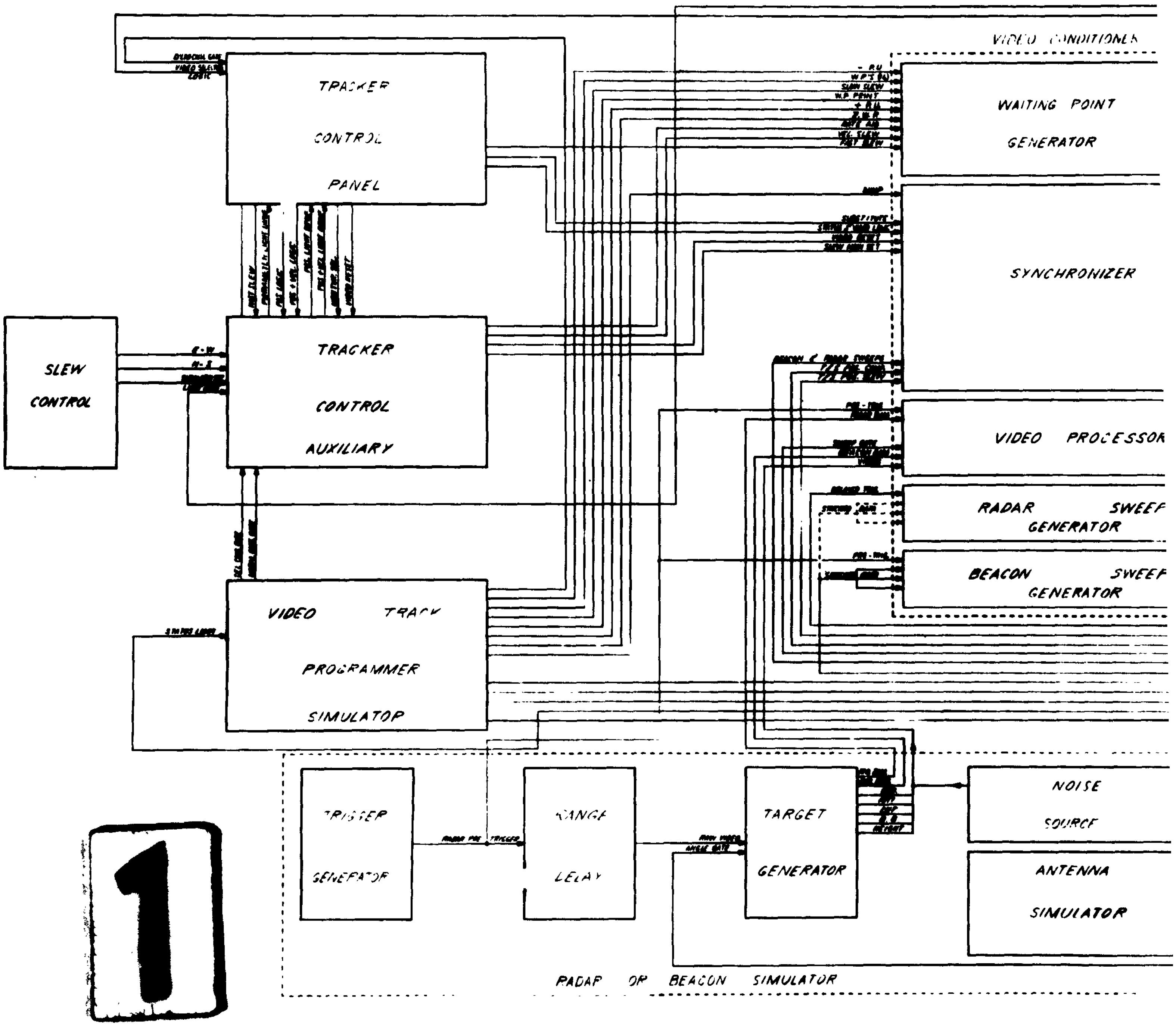
2.1.1.3 PAR CONSOLE ACCEPTANCE TEST - Tests were performed in accordance with the latest revision of the PAR Console Acceptance Test Specification (TIC Specification 1133) in order to check the electrical design of the PAR Console and its compatibility with the PAR-1 and FPN-16 Radars. Other test objectives were to predetermine the reliability and stability of the PAR Console, and to demonstrate its performance under simulated operating conditions.

The procedure did not include the testing of communications equipment, the Wickes Clock or the PAR Approach Display Assembly, as these items were either GFE or were covered by other acceptance test procedures.

2.2 HISTORY OF UNIT TEST 7

The results of Unit Test 7 are given in Table 5 for each section of the applicable test specification, namely, TIC Specification 1145. The Table also indicates the number of Trackers tested, the number of Trackers accepted and data concerning Tracker peripheral equipment tests. The sections which were partially passed are indicated by an asterisk in Table 5. These sections are explained in detail in Section III, Conclusions and Recommendations. The following paragraphs describe the history of Unit Test 7, including the problem areas encountered in the earlier phases of the testing and the solutions and/or decisions reached on each.

A pre-run of Unit Test 7 was performed in September 1960 by TIC and GPL personnel to debug the alignment and test procedures and to familiarize test and observer personnel with the procedures. A formal run of Unit Test 7 was made in late September and early October, with FAA representatives recording test results.


TRACKER CONTROL PANEL
SLEW CONTROL
TRACKER CONTROL AUXILIARY
VIDEO TRACK PROGRAMMER SIMULATOR
WAITING POINT GENERATOR
SYNCHRONIZER
VIDEO PROCESSOR
RADAR SWEEP GENERATOR
BEACON SWEEP GENERATOR
TRIGGER GENERATOR
RANGE DELAY
TARGET GENERATOR
NOISE SOURCE
ANTENNA SIMULATOR
RADAR OR BEACON SIMULATOR
1

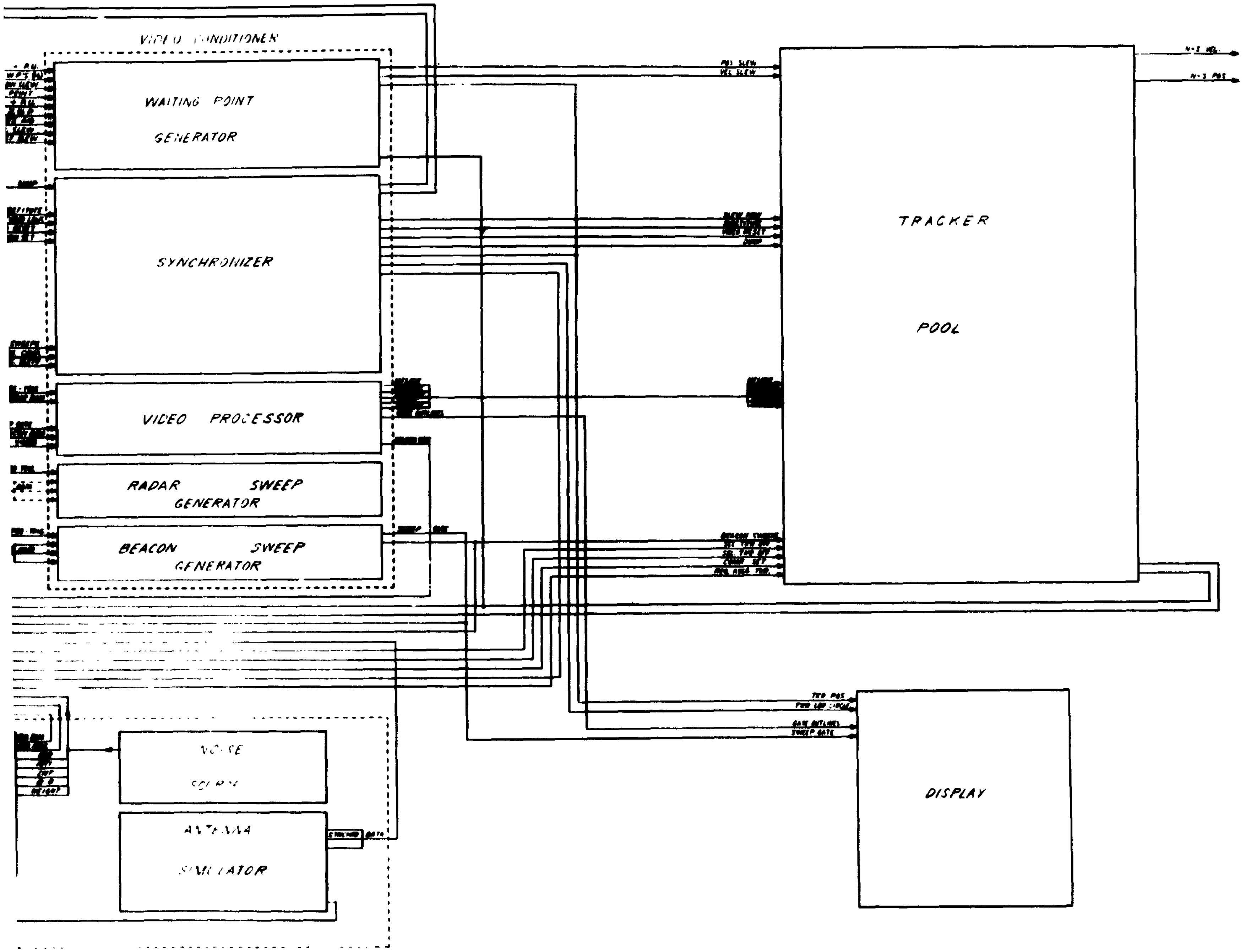


Figure 52. Unit Test 7, Block Diagram

Problem areas (listed in Table 6) were defined during this period and the relative importance of each problem established. A priority was then placed on the problems as to which would be fixed and the order of accomplishing the changes. Solutions to the major items were pursued by TIC, as authorized by GPL, in accordance with the above mentioned priority. On 2 November and 3 November, 1960, an informal recheck was made of items 20, 17, 23, 14, 8 and 21 (Table 6) to demonstrate to FAA representatives progress in correcting equipment problem areas. Additional testing was conducted from November 8 through November 13, 1960 to prove circuit changes and to align circuits. The Unit Test 7 equipment was prepared for shipment starting November 14, 1960 and shipped on November 28, 1960.

2.2.1 EQUIPMENT TESTED

The following equipments were interconnected and tested as a functional group:

a. Video Trackers (6 out of 25)
b. Two Video Tracker Units (Serial No. 1 and 2)
c. Conditioner-Generator Unit Type II (Serial No. 2)
d. Video Processor Assy (Serial No. 1)
e. Waiting Point Generator Assy (Serial No. 1)
f. Synchronizer Assy (Serial No. 1)
g. Precision Sweep Generator Assy (Serial No. 3 and 4)
h. Tracker Control Group
    1. Tracker Control Panel (Serial No. 6)
    2. Slew Control Unit (Serial No. 3)
    3. Tracker Control Auxiliary (Serial No. 5)

The ground rules for selecting Trackers for Unit Test 7 were as follows:

Six Trackers were initially to be selected for the quantitative test of Tracker performance. In the event that one of the selected Trackers failed a section of the Unit Test 7 specification, another Tracker would be substituted until six Trackers passed the test or until 25 Trackers had been tested. It was also ruled that if six Trackers passed a section of the Unit Test 7 specification, that section was considered passed regardless of the number of Trackers substituted. The result of this test method is outlined in Table 5.

2.2.2 TEST METHODS AND TEST EQUIPMENT

All subassemblies were aligned per applicable TIC alignment specifications (refer to TIC 1145 section 3.0). All interconnections were made as described in specifications listed in TIC 1145 section 3.2. A breadboard radar and beacon video simulator was constructed and used to simulate the video to be tracked.

The simulator was aligned as required to satisfy radar and beacon test signal requirements per TIC Specification 1145. A Video Track Programmer Simulator breadboard was also constructed for these tests. This simulator provided input control signals to the Trackers in place of the Video Track Programmer, which was not then available. A special PPI display unit test fixture which presented a time-shared radar/slew-dot display provided a convenient means for simultaneous monitoring of all selected Trackers, tracking gate size, Tracker lock-on waiting-point position and Tracker stability. A Resolver Alignment Assembly, TIC 4798, was also provided for alignment of the sweep generator when demonstrating the full prf range of operation. Further, a Sweep Comparator Assembly, TIC 4801, was designed to facilitate measurement of the precision sweep slope and linearity.

Commercial test equipment used was as follows:

a. Oscilloscope, Tektronix 535 with 53/45C and 53/54D plug-in unit.
b. Vacuum Tube Voltmeter - John Fluke Model 801.
c. Multimeter - Simpson 260
d. Pulse Generator - Hewlett Packard Model 212A
e. Pulse Counter - Hewlett Packard 524D with 526B plug-in unit.
f. Audio Signal Generator - Hewlett Packard Model 200 CD
g. Digital D-C Voltmeter - Non-Linear Systems Model 481
h. Isolation Transformer - 115-Volt AC 60-cps, 1:1 turns ratio.
i. Precision Voltage Reference - Epsco Model 607 VR

2.2.3 PROBLEM AREAS

A meeting of GPL, FAA and TIC personnel was held on October 6, 1960 to define the problem areas (listed in Table 6) as a result of the FAA witnessed Unit Test 7. After listing the problem areas, their relative importances were determined and the problems were classified in two categories as listed below, viz, (A) Items to be corrected before November 1 and (B) Study and/or modification kit items.

CATEGORY A Items (Before Nov. 1st)	CATEGORY B Items (Studies & Mod. Kits)
25	3
19	14
11	6
10	7
20	16
15	8
17	21
23	1
9	5
18	2
28	
22	

TABLE 5. TEST RESULTS, UNIT TEST 7

TIC Spec 1145 Sec. No.	Functions Tested	Results	Trackers Passed/Tested
5.1	Turn on Procedure	Passed	
5.2	Tracker Call-up and Initial Conditions	Passed	7/7
5.3	Waiting Points	Passed	10/12
5.4	Radar Tracking Gate	Passed	11/12
5.5	Position Slew	Passed	8/8
5.6	Position + Velocity Slew	Passed	6/6
5.7	2-D Radar Automatic Tracking	Passed	19/23
5.8	2-D Coast	Passed	10/13
5.9	2-D Radar Tracking Gate Size and Status Indication	*Passed	
	*Subparagraphs 5.9.1 through 5.9.13 were passed with the exception of 5.9.8 and 5.9.9.		
5.10	Radar Target Cross-Over	Passed	4/4
5.11	Basic Beacon Target Cross-Over	Passed	5/6
5.12	2-D Beacon Automatic Tracking	Passed	19/23
5.13	2-D Beacon Gate Size and Status Indication	*Passed	
	*Subparagraphs 5.9.1 through 5.9.13 were passed with the exception of 5.9.8 and 5.9.9.		
5.14	3-D Waiting Points	Passed	7/15
5.15	Z Beacon Target Search	*Passed	
	*Subparagraphs 5.15.1 through 5.15.13 passed all the requirements of Unit Test 7 except 5.15.9.		
5.16	3-D Beacon Automatic Tracking	Passed	10/12
5.17	3-D Coast	Passed	11/14
5.18	Procedure for Switching to 3-D Radar	Passed	
5.19	Z Radar Target Search	Passed	6/14
5.20	3-D Radar Automatic Tracking	Passed	6/8
5.21	Compute Sequence Signals	Passed	
5.22	Substitute	Passed	3/3
5.23	Tracker Control Panel	Passed	
5.24	Radar Video Standardization	Passed	
5.25	Radar Video Outputs to the Display System	Passed	
5.26	Beacon Video Standardization	Passed	
5.27	Radar Pre-Trigger Delay	Passed	
5.28	Sweep Generator Test	Passed	

TABLE 5. TEST RESULTS, UNIT TEST 7 (continued)

TIC Spec 1145 Sec. No.	Functions Tested	Results	Trackers Passed/Tested
5.29	Beacon Sweep Inputs	Passed	
5.30	Beacon Negative Sweep Gate	Passed	
5.31	Beacon Resolved Sweep Level	Passed	
5.32	Beacon NS Sweep Slope and Linearity	Passed	
5.33	Beacon EW Sweep Slope and Linearity	Passed	
5.34	Beacon PRF Range	Passed	
5.35	Beacon Sweep Output Impedance	Passed	
5.36	Beacon Sweep Output Noise	Passed	
5.37	Beacon Servo	Passed	
5.38	Beacon Servo Following Error	Passed	
5.39	Radar Sweep Generator Test	Passed	
5.40	Tracker Accuracy	Passed	
5.41	Reference Voltage to A/D Converter	**Passed	
5.42	Mechanical Specs. of Tracker Controls	Passed	

**Modified and retested but not witnessed by FAA.

TABLE 6. PROBLEMS, UNIT TEST 7

Problem	TIC 1145, Section	Disposition
Item 1: Width of tracking gate outline was 2 us instead of 1 us as specified.	5.4: Radar Gate Tracking	TIC not authorized to fix. GPL accepted 2 us gate.
Item 2: Slew Stick handling somewhat awkward from human engineering standpoint.	5.4: Radar Gate Tracking	TIC provided a large and small slew stick to NAMTC. One-hour training interval required for gaining efficiency in the use of the small slew stick.
Item 3: Rate-aided tracking failed to slew properly in position-plus-velocity mode.	5.6: Position-Plus-Velocity Slew.	The Waiting Point Generator was corrected. Time was not available for retest. Operation satisfactory to TIC.
Item 4: Radar tracking not passed by some trackers which lost targets making procedural turn.	5-7: 2-D Radar Automatic Tracking	During the course of Unit Test 7, dynamic tracker alignment procedures were adopted to eliminate alignment errors contributing to improper tracking of accelerating targets. This change together with reduction of gate delay and addition of front-panel potentiometers and test points, greatly improved tracking of accelerating targets as demonstrated by subsequent informal tests conducted Nov. 2 and 3, 1960.

TABLE 6. PROBLEMS, UNIT TEST 7 (continued)

Problem	TIC 1145, Section	Disposition
Item 5: Difficult procedure in 1200-knot 5-minute coast test.	5.8: 2-D Coast.	This was resolved to be a test procedure and alignment problem as corrected in Item 4 above.
Item 6: Tracking gate size expansion with range incorrect.	5.9: 2-D Radar Tracking Gate Size and Status Indication.	Some Trackers found to have wiring error and corrected. Problem resolved to the satisfaction of TIC. Time not available for final retest.
Item 7: Tracking at low data rates during 2-D Beacon tracking was failed by some Trackers which lost an accelerating target.	5.11: Basic Beacon Target Cross-over.	Same as Item 4
Item 8: Z target search tests failed when Trackers lost lock-on in 3-D tracking.	5.15: Beacon Z Target Search.	This was remedied by replacement of diodes which had failed or by correctly installing diodes which were installed backwards.
Item 9: Tracker Control Panel improper mechanical fit.	Quality Control Item.	Corrected prior to shipment.
Item 10: Orgin blanking 3 to 33 us instead of 12 to 60 us.	5.10: Radar Target Cross-over.	Resolved by changing an r-c time constant.

TABLE 6. PROBLEMS, UNIT TEST 7 (continued)

Problem	TIC 1145, Section	Disposition
Item 11: Drift of print coordinate bus op. amp. in Synchronizer	5.40: Tracker Accuracy.	Synchronizer op. amp. replaced with improved design.
Item 12: Tracker drifts.	5.40: Tracker Accuracy.	Same as Item 4.
Item 13: Waiting Point Generator	5.3: Waiting Points.	Waiting Point Generator modifications were implemented and evaluated to TIC satisfaction. Time was not available for final retest. Box test completed before shipment.
Item 14: Synchronizer op. amps. misaligned, affecting slew dot and Mode B circle position accuracy.	5.40: Tracker Accuracy.	Same as Item 11.
Item 15: Radar-Beacon relays hangup due to low dropout voltage-current.	5.4: Radar Tracking Gate. 5.11: Basic Beacon Target Crossover.	This problem was eliminated by addition of two diodes and two resistors to the Trackers
Item 16: Gate delay in Tracker affected acceleration tests adversely.	5.4: Radar Tracking Gate. 5.11: Basic Beacon Target Crossover.	Same as Item 4.

TABLE 6. PROBLEMS, UNIT TEST 7 (continued)

Problem	TIC 1145, Section	Disposition
Item 17: Relay driving transistors ran away under conditions of power failure in $+$ 24 volt d-c circuit of Tracker.	Quality Control Item	Interlock relay circuit installed in the Video Tracker cabinet. (This modification was not authorized on all Tracker cabinets).
Item 18: Conditioner-Generator Unit No. 1 wiring changes recommended to accept improved Character Generator.	Quality Control Item	Corrected prior to shipment.
Item 19: Coaxial connections erratic on Tracker racks.	Quality Control Item	Corrected prior to shipment. (This modification was not authorized on all Tracker cabinets).
Item 20: Time to indicate Tracker off target not set at 25 seconds; some Trackers timed out at 12 seconds.	5.40: Tracker Accuracy	Circuits were corrected by installation of capacitors to lengthen the time interval.
Item 21: Small Z gate indication not obtained from some Trackers.	5.15: Beacon Z Target Search.	Same as Item 8.
Item 22: 2D-3D switch in Tracker wired backwards and not labeled 2D-3D.	5.18: Procedure for switching to 3-D radar.	Switches rewired and labeled.

TABLE 6. PROBLEMS, UNIT TEST 7 (continued)

Problem	TIC 1145, Section	Disposition
Item 23: Radar on-gate level incorrect.	5.4: Radar Tracking Gate.	Corrected by changing a resistance value in the Precision Sweep Generator.
Item 24: 3-D tracking with ½ mile gate and 30-rpm antenna scan failed to maintain track with two Trackers.	Deleted from TIC tests	This was a test equipment problem. Also see solution of Item 4.
Item 25: Noise test not performed.	Deleted from TIC tests	This item tested to TIC satisfaction. Appropriate test equipment not available at TIC.
Item 26: Schedule circles not stable and not printing at 100 miles.	Deleted from Test. To be performed in Unit Test 8.	Same as Item 11.
Item 27: Tracking pulse output in Z track not at proper level per GPL Specification 10000-523.	Deleted from test.	GPL requested that no action be taken because the pulse is no longer required as an output signal Output impedance was lowered to meet equipment requirements prior to shipment.

TABLE 6. PROBLEMS, UNIT TEST 7 (continued)

Problem	TIC 1145, Section	Disposition
Item 28: General quality inspection items.	Quality Control Item.	Equipment cleanup was performed to prepare for final inspection.
Item 29: Sweep linearity not per specification.	5.29: Beacon Sweep Inputs.	Faulty test equipment. This test was previously passed in final box tests prior to first shipment to GPL and in other sections of TIC 1145.
Item 30: Power supply overvoltage alignment specification not released.	Quality Control Item.	Correcteu prior to shipment.
Item 31: Power supply fusing marginal	Quality Control Item.	Corrected prior to shipment.

Items 4, 12, 13, 24 and 26 of Table 6 are not listed above since they are in effect, sub areas of certain other items listed above.

Problems corrected and successfully tested by TIC prior to shipment of the equipment (but where the test was not observed by FAA and has not been subsequently performed at NAFEC) are listed in the final Unit Test 7 Specification as sections "not tested".

2.3 HISTORY OF UNIT TEST 8

The results of Unit Test 8 are given in Table 7 for each section of the applicable test specification, namely, TIC Specification 1148. The tests demonstrated that the equipment would operate in a group as a video tracking system and as a display data processing equipment. Certain tests and test results are explained in detail in Section III, Conclusions and Recommendations.

The following describes the History of Unit Test 8, including problem areas which were encountered during the earlier phases of the testing.

A pre-run of Unit Test 8 was performed in mid-November 1960 by TIC personnel in order to debug the alignment and test procedures and to familiarize test and observer personnel with the procedures. A formal run of Unit Test 8 was made in late November and early December 1960 with FAA representatives recording test results.

The Unit Test 8 test setup and the Register Simulator breadboard unit were not authorized sufficiently in advance of the Unit Test 8 pre-run to allow time for adequate inter-unit checkout and to perform Video Track Programmer wiring changes which would have resulted. The test schedule had been advanced from 12 December to 28 November 1960 in order to combine GPL preliminary tests and FAA acceptance test with the Unit Test 8 test run. As a result, it was not possible to complete Unit Test 8 in the time allotted. However, most of the tests were completed and the more important items of the remaining sections were demonstrated to FAA and GPL personnel to show that the equipments would function properly as a group. Subsequent tests at NAFEC verified the uncompleted items of Unit Test 8.

2.3.1 EQUIPMENT TESTED

The following equipments were interconnected and tested as a functional group:

a. Video Track Programmer Type I (Serial No. 1)
b. Two Video Tracker Units (Serial No. 2 and 3)
c. Eighteen Video Trackers (Serial No's. 1, 2, 5, 8, 9, 10, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 24 and 25)

d. Three Tracker Control Groups consisting of:

   1. Three Tracker Control Panels (Serial No. 3, 4 and 5)
   2. Three Slew Control Units (Serial No. 4, 5 and 6)
   3. Three Tracker Control Auxiliaries (Serial No. 3, 4 and 6)

e. Conditioner-Generator Unit, Type I (Serial No. 1) containing items f through j, below)

f. Video Conditioner consisting of:

   1. Waiting Point Generator (Serial No. 1)
   2. Synchronizer (Serial No. 2)
   3. Video Processor (Serial No. 2)
   4. Two Precision Sweep Generators (Serial No's 1 and 2)

g. TCP Lamp Driver (Serial No. 1)

h. Digital to Analog Converter (Serial No. 1)

i. Approach Display Processor consisting of:

   1. Display Processor, Conversion (Serial No. 1)
   2. Display Processor, Control (Serial No. 1)

j. Character Generator consisting of:

   1. Logic Assembly (Serial No. 2)
   2. Converter Assembly (Serial No. 2)

k. Local Approach Display (Serial No. 1)

l. PAR Approach Display (Serial No. 1)

The ground rules for conducting Unit Test 8 were as follows:

Test priorities were to be given to those items not previously tested regardless of their order of occurrence in the Test Specification. The tests to be performed were to be selected by TIC. Shut downs during normal test periods (9AM to 5PM) were not to exceed one half-hour unless no further testing could be performed until the discrepancy was fixed. Basic tests were to be of first concern with detail testing permitted only if time was available. Testing of peripheral equipment (Character Generator) in concurrence with Unit Test 8 tests was to be acceptable, as long as the tests did not require the Video Track Programmer as an input device.

2.3.2 TEST METHODS AND TEST EQUIPMENT

All items to be tested were interconnected in accordance with TIC Inter-Cabinet Diagrams 5335 and 5839. The Unit Test 8 tests performed were grouped according to five main sections as follows:

a. Input-Output Operation
b. Tracker Control (one-pool)

c. Tracker Control (two-pool)
d. Approach Display Control
e. Outputs to PPDD Equipment

Input messages were sent to the Video Track Programmer (VTP) from the R Register Simulator. Outputs and inter-equipment operation were checked by observing presentations on a simulated PPD Display, by checking waveforms, by measuring voltage levels at outputs, by observing Tracker Control Panel status indications, and by observing the Approach Display presentations. The output messages from the VTP to the Air Traffic Control Data Processing Central were checked by observing VTP front-panel status lamp indications and by checking waveforms.

Since a PPDD was not available for use during the test, a simulated PPDD was assembled to show most of the display outputs and to demonstrate that the display would be presented correctly. In addition, it was necessary to perform extensive checks on signal waveform characteristics to demonstrate conformance with the TIC Specification 1148. The simulated PPDD did not have the capability of printing characters. However, it did display a dot where each character would appear in the actual PPDD.

The R Register Simulator was used for programming the various messages to the Video Track Programmer. The simulator was constructed to scan eight programmable characters. A switch controlled the number of times the scan was repeated during any message. This technique produced a message of any length, but only the first eight characters were as specified. The other characters were repetitions of the first eight characters.

Each test observation and measurement was recorded in the data section of Unit Test 8. During the tests, a log book on the proceedings was kept by GPL and FAA personnel. Special notes and explanatory information were included in the log.

Commercial test equipment used was as follows:

a. Oscilloscope, Tektronix Model 535 and 545 with 53/54[illegible] plug-in amplifier and P7 phosphor

b. Oscilloscope, Tektronix Model 536
c. DC Voltmeter, Simpson Model 260
d. Precision Voltage Reference, EPSCP 607VR

2.3.3 PROBLEM AREAS

A meeting of FAA, GPL and TIC personnel was held on December 16, 1960 to review the problems which came up during the FAA-witnessed Unit Test 8. A total of 16 problem areas were discussed, in which the test paragraphs had not been passed or only partially passed. Eight of the 16 items were in the category

of partial acceptance. The major causes of the 16 problems were the circle generation function and alignment of the Digital to Analog Converter. In the test paragraphs which were not passed and which involved the Video Track Programmer, the basic capability of the equipment to operate satisfactorily had been proved and it was mutually agreed that completion of logic and wiring error connections would resolve these problems.

As a result of the changes to the Video Track Programmer during the interval of December 16 through December 28, all functions of the Video Track Programmer and Digital to Analog Converter were proved acceptable (at NAFEC). Only those functions concerned with circle and cross generation have not yet been tested at NAFEC.

2. 4 HISTORY OF PAR CONSOLE ACCEPTANCE TESTS

The results of the PAR Console Acceptance Test are summarized in Table 9 for each section of the applicable test specification (TIC Specification 1133) which expresses the final agreements reached between FAA, GPL and TIC personnel as regards functions to be tested. All sections and sub-sections of this specification were either passed, with the exception of the sweep straightness tests as noted in Table 9 and explained in paragraph 2. 4. 3. 1 of this report, or the circuits were subsequently repaired and are capable of passing the test requirements. The sections which were partially passed are indicated by an asterisk in Table 8. These sections are explained in detail in Section III, Conclusions and Recommendations.

The following paragraphs describe the history of the PAR Console Acceptance Tests, including problem areas encountered during the progress of the tests and the solutions and/or decisions reached on each problem area.

A pre-run of the PAR Console acceptance test was performed during October and November, 1960 by TIC and GPL personnel to debug the alignment and test procedures and to familiarize test and observer personnel with the procedures. A formal run of the PAR Console Acceptance Test was performed during November and December, 1960, with FAA representatives recording test results. Evaluation of test results led to further revisions to the test procedure to the agreement of FAA, GPL and TIC personnel. Quality control inspection and testing was performed concurrently with and immediately following the PAR Console Acceptance Tests, and delivery was made on December 30, 1960.

2. 4. 1 EQUIPMENT TESTED

The PAR Console was tested while connected to the PAR Console Test Set (TIC Part No. 5999). The ground rules for performing the PAR Console Acceptance Tests were as follows: The remote control functions for use with the FPN-16

TABLE 7. TEST RESULTS, UNIT TEST 8

TIC Spec 1148 Section	Functions Tested	Results
	Input-Output Operation	
6. 1. 1. 1	Function Code Parity	Passed
6. 1. 1. 2	Short Message Parity	Passed
6. 1. 1. 3	Long Message Parity	Passed
6. 1. 1. 4	N Times Parity	Passed
6. 1. 1. 5	Message Interrupt	Passed
6. 1. 2	Input Message	Passed
6. 1. 3. 1	Line Characteristics	Passed
6. 1. 3. 2	Read Gate Missing	Passed
	Tracker Control (One-Pool)	
6. 2. 1	Tracker Request	Passed
6. 2. 2	TCP Lamp A1 Blinks Dimly	Passed
6. 2. 3	Update of Trackers	Passed
6. 2. 4	Video Tracker Selection	Passed
6. 2. 5	Dump Tracker	Passed
6. 2. 6	Dump Tracker (TCP0	Passed
6. 2. 7	In Use Lamp Illuminates (04)	Passed
6. 2. 8	Characters are Correct	Passed
6. 2. 9	Tracker 04 Maintenance lamp on, In Use lamp off	Passed
6. 2. 10	Trackers Substitute Properly	Passed
	Tracker Control (Two-Pool)	
6. 3. 1	In Use Lamp on Tracker (01) Lights (No Others)	Passed
6. 3. 2	Lamp A1 is Extinguished	Passed
	Approach Display Control	
6. 4. 1. 1	Start-up Message is Correct	Passed
6. 4. 1. 2	Approach Displays are Correct	Passed
6. 4. 2. 1	Output Message is Correct	Passed
6. 4. 2. 2	Ladders Down Correctly, New Identity in Top Row	Passed
6. 4. 3. 1	Output Message is Correct	Passed
6. 4. 3. 2	Sixth Row Does Not Change, Ladders Down Correctly	Passed
6. 4. 4	Time Display is Correct	Passed

TABLE 7. TEST RESULTS, UNIT TEST 8 (continued)

TIC Spec 1148 Section	Functions Tested	Results
	Print Cycle Operation	
6.5.1	System Erase	Passed
6.5.2	Loading the Drum	Passed
6.5.2.1	All Messages Sent	Passed
6.5.2.2	Observing Displays	Passed
6.5.2.2.1	Leaders Extend from Center to Character Groups Northwest and Northeast	Passed
6.5.2.2.1.1	No Bar when Tracker is Locked On	Passed
6.5.2.2.2	Character Group Appears at End of South Leader	Passed
6.5.2.2.3	Serrated Leader Extends North	Passed
6.5.2.2.4	3 Character Groups Appear at ends of Northwest, Northeast and East leaders	Passed
6.5.2.2.5	3 Character Groups and Leaders are Correct	Passed
6.5.2.2.6	Correct East Leader and Character Group with full Bar Appears	Passed
6.5.2.2.6.1	Landing Sequence Disappears	Passed
6.5.2.2.6.1.1	Noise is less than 0.015v RMS	Passed
6.5.2.2.6.2	Character Intensity noise (during TCP Display Gate) is at least 20 db Below Peak of Intensity Pulse	Passed
6.5.2.2.6.3	Gross Positioning Goes to + 20v	Not Tested
6.5.2.2.7	Scramble	Passed
6.5.2.2.7.1	Crosses appear correctly	Passed
6.5.2.2.8	Correct Character Groups Appear	Passed
6.5.2.2.8.1	2 Circles Appear at Correct Places	Passed
6.5.2.2.8.1.1	Voltage Levels Within 20 mv of Final	Passed
6.5.2.2.8.1.2	Sine Wave is Correct Frequency	Not Tested
6.5.2.2.8.1.3	Circle Intensity Timing is Correct	Passed
6.5.2.2.8.1.4	Signals Stay Within .05v of Correct Value	Not Tested
6.5.2.2.8.1.4.1	Average Level Varies Less Than 10 mv	Not Tested
6.5.2.2.8.1.4.2	Noise is Less than 3 mv	Not Tested
6.5.2.2.8.1.5	Average of (N-S) Sine Wave, (E-W) Sine Wave	Not Tested
6.5.2.2.8.1.6	Output Resistance is 93 ohms ±10%	Passed
6.5.2.2.8.1.7	Circle Radius Constant ±10%	Not Tested
6.5.2.2.8.1.8	Circle Leader Slope is Correct	Passed
6.5.2.2.9	Corridor Display (Return to Base) Appears Properly	Passed
6.5.2.2.10	Character Group With Full Bar on West Leader	Passed
6.5.2.2.10.1	Tracker Display Moves From TCP #9 To TCP #7	Passed

TIC Spec 1148 Section	Functions Tested	Results
	Character Generator Gate	
6.5.2.2.11.1.1	TCP Gate Timing	Passed
6.5.2.2.11.1.2	Intensity Pulses Occur at Least 25 μsec After Signal Appears on Busses	Passed
6.5.2.2.11.1.3	Intensity Pulses Occur at Least 25 μsec After Signal Appears on Busses	Passed
6.5.2.2.11.1.4	Circle Display Gate Timing	Passed
6.5.2.2.11.1.5	Intensity Pulse Occurs at Least 10 μsec After a Change On Offset and Incremental Busses	Passed
6.5.2.2.11.1.6	Intensity Pulses All Occur at Least 20 μsec after the Spot During Character Gate Comes On	Passed
6.5.2.2.11.1.6.1	No Intensity Pulse Occurs Within 20 μsec After Spot During Character Gate Turns Off	Passed
6.5.2.2.12.1	Spot During Character Gate, Amplitude	Passed
6.5.2.2.12.1.1	Base line	Passed
6.5.2.2.12.1.2	Timing OK	Passed
6.5.2.2.12.1.3	Rise time	Passed
6.5.2.2.12.1.4	Fall time	Passed
6.5.2.2.12.2.1	Circle Display Gates, Amplitude	Passed
6.5.2.2.12.2.1.1	Base line	Passed
6.5.2.2.12.2.1.2	Duration, about 3 Characters	Passed
6.5.2.2.12.2.2	Circle Intensity Pulse, Amplitude	Passed
6.5.2.2.12.2.2.1	Base line	Passed
6.5.2.2.12.2.2.2	Width, About 2 Characters	Passed
6.5.2.2.12.2.2.3	Rise Time	Passed
6.5.2.2.12.2.2.4	Fall time	Passed
6.5.2.2.12.2.2.5	Overshoot	Passed
6.5.2.2.12.2.3.1	Circle Leader Intensity Pulse, Amplitude	Passed
6.5.2.2.12.2.3.2	Base line	Passed
6.5.2.2.12.2.3.3	Rise Time	Passed
6.5.2.2.12.2.3.4	Fall Time	Passed
6.5.2.2.12.2.3.5	Overshoot	Passed
6.5.2.2.12.2.3.6	Width Greater Than 50 μsec	Passed
6.5.2.2.12.2.3.7	Width Reduces to 10 μsec, Increases to More than 50 μsec	Passed
6.5.2.2.12.2.4	Circle Leader Slope	Passed
6.5.2.2.12.2.4.1	No Hooks or Wiggles Greater Than 0.5v Deviation from a Straight Line	Passed
6.5.2.2.12.2.4.2	Slope	Passed
6.5.2.2.12.2.4.3	No Hooks or Wiggles Greater than 0.5v Deviation from a Straight Line with .05 ±10% Linearity	Passed

TABLE 7. TEST RESULTS, UNIT TEST 8 (continued)

TIC Spec 1148 Section	Functions Tested	Results
6. 5. 2. 2. 12. 3.	TCP Display Gates	Passed
6. 5. 2. 2. 12. 4	Override Call-Up Gate, Amplitude	Passed
6. 5. 2. 2. 12. 4. 1	Off Level	Passed
6. 5. 2. 2. 12. 5. 1	Offset and Incremental Bus, Offset Leaders	Passed
6. 5. 2. 2. 12. 5. 2	Leader Lengths	Passed
6. 5. 2. 2. 12. 6	Character Intensity Pulses, Amplitude	Passed
6. 5. 2. 2. 12. 6. 1	Base line	Passed
6. 5. 2. 2. 12. 6. 2	Adjusts to 10 μsec	Passed
6. 5. 2. 2. 12. 6. 3	Adjusts to 30 μsec	Passed
6. 5. 2. 2. 12. 6. 4	Rise Time	Passed
6. 5. 2. 2. 12. 6. 5	Fall Time	Passed
6. 5. 2. 2. 12. 6. 6	Overshoot	Passed
6. 5. 2. 2. 12. 6. 7	Line Selection	Passed
6. 5. 2. 2. 12. 7	Bar Intensity Pulse Amplitude Same as Normal Leader Intensity Pulse Amplitude	Passed
6. 5. 2. 2. 12. 7. 1	Pulse Length	Passed
6. 5. 2. 2. 12. 7. 2	Rise Time	Passed
6. 5. 2. 2. 12. 7. 3	Fall time	Passed
6. 5. 2. 2. 12. 7. 4	Pulse Length	Passed
6. 5. 2. 2. 12. 8	19 Character Group Appears	Passed
6. 5. 2. 2. 12. 8. 1	Group Size Adjusts to 2" x 2" ±1/8"	Passed
6. 5. 2. 2. 12. 8. 2	Group Size Adjusts to 1/2" x 1/2" ±1/8"	Passed
6. 5. 2. 2. 12. 8. 3	Group Size Adjusts to 1" x 1" ±1/8"	Passed
6. 5. 2. 2. 12. 9	1/2 Bar	Passed
6. 5. 2. 2. 12. 9. 1	Full Bar	Passed
6. 5. 2. 2. 12. 10	Special Display 7 Character Group Appears	Passed
6. 5. 2. 2. 12. 10. 2	Call-Up Group Location	Passed
6. 5. 2. 2. 12. 11	Horizontal Group Spacing Adjusts to 1" ±1/8"	Passed
6. 5. 2. 2. 12. 11. 1	Horizontal Group Spacing Adjusts to 2" ±1/8"	Passed
6. 5. 2. 2. 12. 11. 2	Vertical Group Spacing Adjusts to 1/2" ±1/8"	Passed
6. 5. 2. 2. 12. 11. 3	Vertical Group Spacing Adjusts to 1" ±1/8"	Passed
6. 5. 2. 2. 12. 12. 1	Offset and Incremental Bus - Leader and Bar Slope, Offset Leader Slope	Passed
6. 5. 2. 2. 12. 12. 2	Bar Slope	Passed
6. 5. 2. 2. 12. 13. 1	Leader and Bar Intensity Pulse, Amplitude	Passed
6. 5. 2. 2. 12. 13. 2	Base line voltage	Passed
6. 5. 2. 2. 12. 13. 3	Adjust to 20 μsec	Passed
6. 5. 2. 2. 12. 13. 4	Adjusts to 40 μsec	Passed
6. 5. 2. 2. 12. 13. 5	Rise time	Passed
6. 5. 2. 2. 12. 13. 6	Fall time	Passed
6. 5. 2. 2. 12. 14	Serrated Leader	Passed
6. 5. 2. 2. 12. 14. 1	Duty Cycle	Passed
6. 5. 2. 2. 12. 14. 2	Amplitude	Passed
6. 5. 2. 2. 12. 14. 3	Level of Dark Space	Passed
6. 5. 2. 2. 12. 15	Normal Leader Intensity Pulse	Passed
6. 5. 2. 2. 12. 15. 1	Adjust Amplitude to 0.5X bright pulse amplitude	Passed

and PAR-1 radar equipments would not be tested in detail by FAA personnel but would be tested in detail by TIC personnel and accepted by FAA. The test paragraphs of the Acceptance Test Procedure which were not acceptable to FAA would be noted on the master copy of the Acceptance Test Procedure by FAA personnel during the progress of the tests and were to be corrected later by TIC/GPL personnel. During the 24-hour test, only normal operator alignments would be allowed. The adjustments which were to be permitted were brightness, erase-pulse amplitude, range-mark intensity, and cursor intensity. Also, during the 24-hour tests the ILS limit lines were superimposed on the cursor glide-slope and course line intensity pulses and their deviation measured. The results of the acceptance test are outlined in Table 9.

2.4.2 TEST METHODS AND TEST EQUIPMENT

All subassemblies were aligned in accordance with the applicable TIC alignment specifications prior to the start of the PAR Acceptance Tests. A radar simulator, consisting of a GFE antenna scan simulator and a TIC-designed PAR Console Test Set, was used to provide input signals to the PAR Console. Considerable difficulty was experienced in utilizing the antenna simulator to generate signals for the relay gate and blanking operations. Open-loop operation of the servo position potentiometers, as recommended by the supplier, was found to be unsatisfactory because accurate positioning of the potentiometers required dynamic braking techniques to overcome gear-train overshoot. Radar signals provided by the PAR Console Test Set did not include video signals and cursor signals for the FPN-16 test mode or video signals for the PAR-1 test mode. Angle-voltage signals were derived from the antenna simulator sine-cosine potentiometer. This potentiometer became erratic, failed and was opened for cleaning many times. Reference and data triggers were generated for PAR-1 simulation in synchronism with the antenna simulator angle volts output and relay gate signals. The simulated system triggers were provided at prf's of 1833 pps and 2000 pps for FPN-16 and PAR-1 operation respectively. Manually variable map limiting L triggers were provided for FPN-16 simulated operation.

Commercial test equipment used was as follows:

a. D. C. Voltmeter (John Fluke or equivalent).
b. Oscilloscope, Tektronix Model 535 with 53/54C plug-in Amplifier.
c. Electronic Counter, Hewlett-Packard 522B or equivalent.
d. Pulse Generator, Rutherford Model 57 or equivalent.
e. Spectra Brightness Spot Meter type SP-1-1/2.

2.4.3 PROBLEM AREAS

A meeting of FAA, GPL and TIC personnel was held at the conclusion of the PAR Console Acceptance Tests on 9 December, 1960. A total of six problems were discussed, four of which involved specification tests. The other two problem areas were academic and were discussions of degree of compliance.

The sweep straightness portion of the test specification was not passed, in that the measured straightness varied from approximately 1/8 to 5/32 inches. The TIC Product Specification No. 1071 specified the maximum variation as 1/8 inch. It was determined from the crt parameters that an expected straightness deviation of a horizontal sweep would be 1/8 inch and, therefore, the limit as specified in TIC Specification 1071 should either be changed to ± 1/4 inch deviation from a straight line or a compensated deflection coil should be designed.

The video amplifier response, as determined by the tests, varied from 0.12 to 0.08 microsecond depending upon the observer. The video amplifier was modified to insure a rise time of less than 0.087 microsecond but not retested.

The line voltage tests of the PAR Console were passed in all major areas, with the exception of the negative 24 volt power supply. Ripple on the 24 volt output caused excessive strobing of the range sweeps and range mark jitter. This problem was satisfactorily solved by replacing a faulty capacitor in the 24 volt power supply.

The twenty-four hour tests of the PAR Console were passed in all major areas with the exception of the 10 KV power supply and intermediate points of measurement in the Elevation and Azimuth Cursor tests. The high-voltage stepup transformer of the 10 KV power supply developed an arc between the filament winding and transformer core. The transformer was replaced and the tests restarted and completed without further trouble. The measurements taken on the Elevation and Azimuth Cursor outputs indicated the second and eighth mile cursor measurements were within tolerance but that the fourth and sixth mile measurements were outside the specified tolerances. Analysis of the test results and circuits indicated that the negative 24 volt power supply had lost a-c regulation and was saturating at normal line voltage. After the power supply had been repaired, the operation of the cursor generator was found to be satisfactory.

The PAR-1 angle voltage demodulation test was attempted using the breadboard PAR Console Test Set and a Tektronix 535 synchroscope. Because these tests could not be repeated, it was determined that the available test equipment was not adequate to meet the requirements of the test specification. Also, exact measurements of the servo potentiometer control tests could not be made for range-mark blanking because of inadequate test fixture control.

TABLE 8. PAR CONSOLE TEST RESULTS

TIC 1133 Section	Function	Test Results
6.1	Angle Voltage Test	Passed
6.2	Relay Gate	Passed
6.3	Blanking Gate	Passed
6.4	Angle Voltage Demodulation	
6.4.1	PAR -1	Not Tested
6.4.2	FPN-16	Passed
6.5	Precision Delay and Gate Circuits	Passed
6.6	Range Marks	Passed
6.7	Sweep Generator	
6.7.1	Sweep Linearity	Passed
6.7.2	Straightness	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deivation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	
6.7.3	Log Sweep	Passed
6.7.4	Log Sweep Straightness	
6.7.4.1	Elevation Straightness	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	
6.7.4.2	Azimuth Straightness	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	
6.7.4.3	Expansion Ratio	Passed

TABLE 8. PAR CONSOLE TEST RESULTS (continued)

TIC 1133 Section	Function	Test Results
6.7.5	Sweep Position	Passed
6.8	Cursor Generator	Passed
6.9	Limit Line -1 Generator	Passed
6.10	Limit Line -2 Generator	Passed
6.11	Map Generator	Passed
6.12	Brightness Measurement	Passed
6.13	Persistence Measurement	Passed
6.14	Video and Intensity	Passed
	Range Resolution	
6.15.1	Video Bandwidth	Not Tested
6.15.2	Range Resolution	Passed
6.16	Sweep Loss Check	Passed
6.17	Focus	Passed
6.18.1	Low Line Voltage	
6.18.1.1	Elevation Cursor Accuracy	Passed
6.18.1.2	Azimuth Cursor Accuracy	Passed
6.18.1.3	Range Marks	Passed
6.18.1.4	Sweep Linearity	Passed
6.18.1.5	Sweep Straightness (Linear)	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	
6.18.1.6	Sweep Straightness (Log)	*Not Passed
	*Calculation on the bulb configuration indicated a minimum deviation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	

TABLE 8. PAR CONSOLE TEST RESULTS (continued)

TIC 1133 Section	Function	Test Results
6.18.1.7	Sweep Length (Log)	*Not Passed
	* The length of the sweep is a direct function of the supply voltage and must have wider tolerance than indicated.	
	Sweep Length (Linear)	Passed
6.18.1.8	Map Alignment	Passed
6.18.1.9	Video Bandwidth	Not Measured
6.18.2	High Line Voltage	
6.18.2.1	Elevation Cursor Accuracy	Passed
6.18.2.2	Azimuth Cursor Accuracy	Passed
6.18.2.3	Range Marks	Passed
6.18.2.4	Sweep Linearity	Passed
6.18.2.5	Sweep Straightness (Linear)	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8". The sum of the bulb and circuit deviation should be 1/4".	
6.18.2.6	Sweep Straightness (Log)	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8". The sum of the bulb and circuit deviation should be 1/4".	
6.18.2.7	Sweep Length (Log)	*Not Passed
	* The length of the sweep is a direct function of the supply voltage and must have wider tolerance than indicated.	
	Sweep Length (Linear)	Passed
6.18.2.8	Map Alignment	Passed
6.18.2.9	Video Bandwidth	Not Measured

TABLE 8. PAR CONSOLE TEST RESULTS (continued)

TIC 1133 Section	Function	Test Results
6.19	24 Hour Tests	
6.19.1	Initial Tests	
6.19.1.1	Elevation Range Accuracy	Passed
6.19.1.2	ILS Limit Line 1 and 2	Passed
6.19.1.3	Azimuth Range Accuracy	Passed
6.19.1.4	Azimuth Limit Line 1 and 2	Passed
6.19.1.5	Range Marks	Passed
6.19.1.6	Sweep Linearity	Passed
6.19.1.7	Sweep Straightness	*Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8''. The sum of the bulb and circuit deviation should be 1/4''.	
6.19.1.8	Sweep Length	Passed
6.19.1.9	Map Alignment	Passed
6.19.1.10	Video Bandwidth	Not Tested
6.19.1.11	Power Supplies	Passed
6.19.2	4 Hour Interval Tests (Summary)	
6.19.2.1	Cursor Deviation	Passed
6.19.2.2	Origin Drift	Passed
6.19.2.3	Range Marks	Passed
6.19.2.4	Sweep Length	Passed
6.19.2.5	Sweep Linearity	Passed
6.19.2.6	Power Supplies	Passed
6.19.3	Final Tests	
6.19.3.1	Elevation Range Accuracy	*Partial
	* End points within tolerance, intermediate points within accepted deviation but outside absolute tolerance.	
6.19.3.2	ILS Limit Line 1 and 2	Passed

TABLE 8. PAR CONSOLE TEST RESULTS (continued)

TIC 1133 Section	Function	Test Results
6. 19. 3. 3	Azimuth Range Accuracy	*Partial
	* End points within tolerance, intermediate points within accepted deviation but outside absolute tolerance.	
6. 19. 3. 4	Azimuth Limit Line 1 and 2	Passed
6. 19. 3. 5	Range Marks	Passed
6. 19. 3. 6	Sweep Linearity	Passed
6. 19. 3. 7	Sweep Straightness (Linear and Log)	Not Passed
	* Calculation on the bulb configuration indicated a minimum deviation of 1/8". The sum of the bulb and circuit deviation should be 1/4".	
6. 19. 3. 8	Sweep Length	Passed
6. 19. 3. 9	Map Alignment	Passed
6. 19. 3. 10	Video Bandwidth	Not Tested
6. 19. 3. 11	Power Supplies	Passed
6. 20	Remote Control Functions	Passed

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

3. 1 GENERAL

This section contains a review of the acceptance test results as outlined in Table 6 for Unit Test 7, Table 8 for Unit Test 8 and Table 9 for PAR Console Acceptance test. In particular, those areas of the tests performed which were partially passed are explained. The corrections are outlined and the disposition of the tests are given. Where test data was obtained from NAFEC between January 16, 1961 and July 6, 1961 and used to indicate passing certain sections of the test specifications, the test paragraphs are indicated. Also contained in this section are recommendations for equipment modifications and test specification/product specification changes deemed desirable by TIC to make the tested equipment more adequate with respect to the DPC system requirement.

3. 2 UNIT TEST 7 CONCLUSIONS

The general results of the Unit Test 7 tests indicate the tracking capability of the Trackers to be in excess of the velocity and acceleration requirements specified for the DPC equipments. Also the operation of the Tracker subsystem (Unit Test 7 test bed) indicated that no major system problems existed and that only circuit improvement changes would be required. The tests, however, did indicate that further study must be given to the equipment during system evaluation at NAFEC to improve reliability and stability. It is the opinion of Tasker Instruments that the reliability of the delivered equipment, as indicated during Unit Test 7, is not typical in that the major reliability problems were personnel errors and/or connector shorts. When these problems were fixed during the test program, the reliability improved substantially.

During the testing at the TIC facility, TIC Specification 1145, paragraphs 5. 4 (Radar Tracking Gate), 5. 6 (Position/Velocity Slew), 5. 11 (Target Cross Over) and 5. 12 (2-D Automatic Tracking) were marginally passed, in that a rather large number of Trackers were tested to accomplish the requirement of six Trackers passing the test paragraphs. Also paragraph 5. 9 (2-D Radar Tracking Gate Size and Status Indication), and paragraph 5. 15 (Z Beacon Target Search) were only partially passed in that certain sub tests of the overall test paragraph were not met. In particular, test 5. 9. 8, 5. 9. 9 and 5. 15. 9 were not passed. These tests involved tracking gate change in size with range and incremental change in altitude per scan. The tests concerning paragraph 5. 40 Tracker Accuracy, were not completed at TIC because of Tracker alignment problems and the marginal operation of the Waiting Point Generator.

The subsequent tests at NAFEC after 30 December 1960 and particularly, after receipt of the Tracker Test Set, proved conclusively that the changes made as a result of the 28 problem area solutions (see par. 2. 2. 3, Section II) resulted in six out of six trackers passing Section 5. 6, 5. 11, 5. 12 and 5. 40. The tests not passed in paragraphs 5. 9 and 5. 15 were not performed again at NAFEC, as changes were not made in the equipment that would warrant such retesting. It is the opinion of Tasker Instruments that the change in gate size with range is sufficient to meet the DPC equipment requirements without modification to the Trackers. Also it is the opinion of Tasker Instruments that the incremental change in altitude during Z Target Search meets the requirements of the DPC system. If future analysis of the DPC system indicated the present tracking gate size change with range is not adequate, known modifications are available to correct this deficiency, as are modifications for correcting the incremental change in altitude per scan concerning Z Target Search.

The pulse width of the tracking gate video as specified in Section 5. 4 (2 microseconds) is not the same as specified for the DPC system. This discrepancy was investigated by TIC and GPL and was resolved as not affecting system operation and accuracy. Therefore, the limit of the test specification is considered to be 2 microseconds.

3. 3 UNIT TEST 8 CONCLUSIONS

The results of Unit Test 8 testing, in general, are considered good to the extent of the ability to perform the tests. The test program was continued after the equipment arrived at NAFEC and approximately 50 per cent of the test results was collected from these tests.

As a result of the combined TIC and NAFEC testing, only subparagraphs 6. 5. 2. 2. 8. 1. 2 through 6. 5. 2. 2. 8. 1. 8 were not tested. These tests are concerned with Mode B circle generation. These paragraphs have not been tested because in the Mode B circle display mode of operation, circles and circle leaders have not been successfully displayed on the PPDD. Cursory checks at the outputs of the TIC equipment indicate the signals are proper. However, until these circles and circle leaders have been properly displayed, TIC does not desire to indicate a passed test.

The problem concerning the approach display tie-in as indicated during the original testing at TIC, was resolved to be a GRS indicator problem. The GRS indicator was specified to always maintain continuity between the contacts of the code wheel and the commutator of the code wheel. Because this continuity is not maintained, slow indicator operation results and/or false null occurs. This problem is being resolved with GRS. In spite of the problems with the GRS indicators, the approach display tie-in operation was tested and passed at NAFEC.

3.4 PAR CONSOLE TEST CONCLUSIONS

The general results of the acceptance testing of the PAR Console indicated that compatible operation with either the PAR-1 radar set or the FPN-16 radar set was assured. Also, the unit met the major requirements of TIC Specification 1133.

During the performance of the acceptance tests for the PAR Console, it was determined from calculations of the crt bulb configuration that the sweep straightness tests as outlined in Sections 6. 7. 4. 1, 6. 18. 1. 5, 6. 18. 2. 6 and 6. 19. 1. 9 could not be met in that the entire tolerance was taken up by the inherent curvature of the glass. Also, as a result of the tests, it was determined that because of the malfunction in the 24 volt power supply the cursor generator drifted out of tolerance during the 24-hour interval. The 24 volt power supply malfunction also resulted in marginal operation of the equipment during low and high line voltage tests. This was particularly emphasized in the sweep length tests of 6. 18. 1. 7 and 6. 18. 2. 7. In particular, the linear sweep maintained its correct length while the logarithmic sweep deviated excessively. A Miller integrator, which is essentially independent of power-supply voltage variations, is used in the linear sweep mode of operation. In the case of logarithmic operation, the sweep generator is an r-c integrator whose output varies directly with the supply voltage. Even though the 24 volt power supply has been corrected for excessive drift, the tolerance for the logarithmic sweep length must be increased in the test specification to include not only sweep and deflection circuit drifts but also such 24 volt power supply drifts as will remain.

The bandwidth of the video system did not pass the initial tests at TIC. The circuits were modified and tested to the satisfaction of TIC to more than meet the requirements of the test specification. In the actual testing prior to delivery, the video bandwidth was met (depending upon the observer). Because the circuit was marginal in the opinion of TIC, the test results as outlined in Table 9 were indicated as not tested.

Tests concerning the PAR-1 Angle Volt Demodulator (test paragraph 6. 4. 1) indicated inability to align the equipment to the required accuracy. During the test interval, the problem was resolved to be inadequate test equipment. Both the PAR Test Set and the Tektronix Type 535 oscilloscope were too coarse in their combined adjustments to facilitate alignment accuracies greater than ±5 microseconds. Thus, the entire tolerance of the test as outlined in test paragraph 6. 4. 1 was consumed in the test equipment. As a result, this test was indicated in the test results of Specification 1133 as not tested.

The correction of the 24 volt power supply malfunction and the change to increase the video bandwidth resulted in the PAR Console being capable of meeting all test paragraphs of TIC Test Specification 1133, with the exception of the aforementioned sweep straightness.

3.5 RECOMMENDATIONS, UNIT TEST 7

The results of the Unit Test 7 tests indicate that the basic design parameters of the Trackers and tracking equipment are sound but that further study and circuit modifications are needed as indicated in the areas indicated below.

The Dynamic Video Standardization (DVS) cards were not tested in Unit Test 7 because of test equipment problems and are not acceptable to TIC, as indicated in all discussions of this circuit and its requirements. A thorough study program is required of all known techniques to accomplish dynamic video standardization and the best features of each system should be combined into a breadboard model for evaluation with the Tracker equipment at NAFEC.

The stability of the present storage amplifier may not meet the requirement of 7 days operation without adjustment. The 100 hour test performed at TIC during the interval of Unit Test 7 indicated that the stability of this circuit is marginal with respect to the DPC requirements. If other testing at NAFEC or a re-run of the 100 hour test at NAFEC indicates that the stability is still marginal, a self-zeroing circuit is recommended. This circuit could be either transistor stabilized or chopper stabilized, in view of the new transistors and transistor techniques available. However, for the present evaluation of the equipment at NAFEC; that is, the immediate needs at NAFEC, a new design is not urgent. The new design is felt necessary for field use of the equipment.

An intensive system reliability study should be started and maintained using Trackers which are maintained in a controlled environment. The personnel supporting this equipment must note each time the power is turned on and off, exactly where any malfunction occurs, and whether or not such power switching was the direct cause of the malfunction. It will only be after this program has progressed that a true reliability analysis of the Video Tracking System can be made. In the interim, malfunctions should be investigated for possible circuit design oversights; for example, overvoltage operation of a transistor during turn on and turn off, and insufficient protection of circuits against radio interference.

The cabinet configuration was proven to be non-optimum during Unit Test 7, in that chassis cannot be operated when extended. It is recommended that an improved cabinet be designed along the lines proposed by TIC in January 1961. This is for future equipment. Because the present equipment will be required for evaluation at NAFEC during the next two year interval, or more, it is recommended that new cabinets incorporating extended cables for each chassis be fabricated for the NAFEC equipment. This will permit any chassis to continue in the operating condition during adjustment or maintenance. Logic circuits must be devised and incorporated to inhibit a Tracker under maintenance from interfering with system operation.

The DPC system requirement should be re-evaluated to determine whether changes should be made in the tracking gate size change with range and the

Z target search height incremental change per antenna scan. The present tracking gate size change ratio is approximately 1.38 as compared with the stated requirement of 1.40. The Z target search increment is approximately 1800 feet as opposed to the stated requirement of 2500 feet. If this system re-evaluation indicates that the present gate size ratio and height incremental changes are operationally insufficient, then known fixes can be incorporated.

The error detector circuit in the Tracker is a linear device. There is evidence that the amplitude of the error pulse, in a system of this type, should not be linear with respect to the deviation of the target from the center of the gate. The system parameters, operating procedures, and radar data rate, along with several other factors, should be used in a detailed mathematical analysis of the tracking loop to determine the optimum error detector response curve.

A precision 3-D target generator should be designed for Tracker maintenance and evaluation. This device should be tape programmed and should provide digital recorder readout of the difference between Tracker coordinates and target coordinates. It is required that the 3-D target generator be capable of generating a minimum of two targets.

3.6 RECOMMENDATIONS, UNIT TEST 8

The results of the Unit Test 8 testing indicate, in general, that the reliability of the equipment is satisfactory and that the equipment operates acceptably under simulated operating conditions but that certain improvements are desirable, as indicated below.

The final tolerances established for the analog signals from the Character Generator to the PPDD Equipments proved the present interconnection scale factors to be non optimum. The tests conducted on the Character Generator indicated compliance with the test specification under simulated conditions. However, in field usage, it is felt that a more optimum system configuration should be utilized. It is suggested therefore that the select and compensation analog signals be changed to binary code lines and that the resistor network for D to A conversion be located in the PPDD Module itself. It is also suggested that the scale factor for the offset and incremental analog signals be decreased. These changes would eliminate the noise problems with respect to select and compensation voltages and would minimize noise problems on the incremental and offset voltage busses. An additional change would be required in the PPDD system to sum call-up position voltages in the display rather than in the Character Generator.

The approach display indicator assemblies (Local and PAR), although meeting the specifications of Unit Test 8, are marginal in operation for field use. In consideration of the problems encountered when using the GRS indicators and in consideration of the requirement to maintain the greatest amount of information in the event of power failure (the reason for tape readouts), it is recommended

that the logic used with the indicators be inverted so that false nulls will not be recognized. It is also recommended that logic be added to prevent 22 indicators from operating simultaneously during start up. Future study should also be conducted concerning the possible requirement for manually energizing the indicator motors in the event of indicator hang up.

A more satisfactory solution which utilizes some of the recently developed, completely electronic readouts is in order. These would eliminate audible and electrical noise, decrease update time, and increase reliability. The electronic readout devices are also more compact and are easier to mount.

As the contract changes increased the complexity of the Video Track Programmer, it became evident that the system would be unmanageable unless some self-checking routines were incorporated. This was done on the basis of what was believed to be a bare minimum of such self-checking routines. In the course of Unit Test 8, it became apparent that the self-checking features were somewhat less than sufficient, but because of the pressure of time only a few minor additions were then made. It is recommended that additional self-checking features be added to facilitate routine maintenance as well as troubleshooting.

During the interval of troubleshooting and testing the Unit Test 8 equipment, it was proven that extender chassis operation is desirable. The present rack configuration requires that the equipment be turned off and separate extender cables be placed between the rack and the chassis before maintenance on individual cards may be accomplished. Because the equipment will be undergoing evaluation at NAFEC during the next two years or more, it is recommended that new cabinets be fabricated which incorporate extender chassis operation. Before this can be accomplished, an investigation must be conducted to prove critical circuits, as necessary.

3.7 RECOMMENDATIONS, PAR CONSOLE

The results of the PAR Console acceptance testing indicate, in general, that electrical design, stability and reliability are acceptable, but that certain improvements are desirable, as outlined below.

At the conclusion of the acceptance testing of the PAR Console, modifications were incorporated to increase the bandwidth of the video amplifier system and to decrease the range of control of the video mapping circuits. Certain other desirable modifications to the PAR Console were not incorporated in the unit because of the delivery schedule but should be incorporated before field usage.

The deflection coil assembly design did not compensate for the curvature of the glass envelope of the cathode ray tube. In discussions of this problem with the deflection coil manufacturer, it was indicated that the bulb curvature can be compensated for in the deflection coil. Thus, for a system using a resolved time base

deflection technique, as used in the PAR Console, the sweep curvature may be essentially eliminated. It is recommended that this development be initiated for both the PAR Console and the PPDD system.

The artificial angle voltage output from the Angle Voltage Test Set was proven to have too coarse an adjustment. This control was changed from a single-turn potentiometer to a 10-turn wirewound potentiometer. As a result, zero angle volts output could not be obtained and the output was observed to jump from wire to wire. Secondly, the voltmeter incorporated in the test set was a 30 volts full scale 1 percent device. As a result, it was not possible to align the cursor generator to the accuracy required using this test set. It is recommended that a digital voltmeter readout device be used in lieu of the present meter and a vernier control be obtained which will ensure zero volts output from the test set.

Alignment controls for the cursor generator and ILS limit line generators should be changed to incorporate a vernier effect. Also, Test Specification TIC 1133 should be changed to measure time delay in microseconds for a fixed angle voltage, rather than angle voltage itself. It is believed that much of the problem concerning cursor alignment and measurement could be prevented by the above testing techniques.

It was found that during turn on of the PAR Console, either the plus or the minus 24 volt power supplies, would not come up to voltage. This phenomenon was caused by an apparent reverse voltage condition in the internal circuit of the power supplies which exists because the deflection amplifiers are floated between plus and minus 24 volts. It is recommended that the deflection coil circuits be changed to operate from a grounded +45 volt supply.